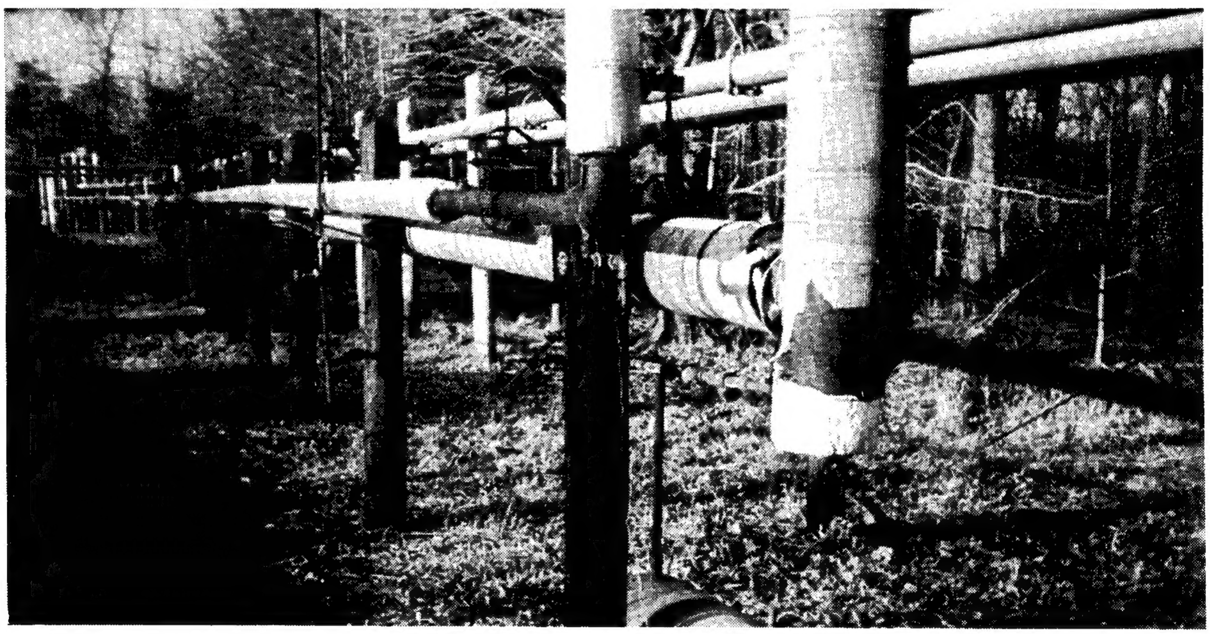
US Army Corps
of Engineers
Construction Engineering
Research Laboratories

USACERL Technical Report 95/02
May 1995

Thermal Energy Supply Optimization for Aberdeen Proving Ground–Edgewood Area

Distribution System Condition Assessment and Recommendations

by
Vicki L. Van Blaricum, Charles P. Marsh, and Vincent F. Hock



This report documents the results of a study by the U.S. Army Construction Engineering Research Laboratories to assess the condition of the steam heat distribution system at Aberdeen Proving Ground (APG)–Edgewood Area (EA), MD. This report documents the portion of the study that addressed widespread corrosion and deterioration existing throughout the aging system.

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The authors developed a detailed set of recommendations that includes (1) replacement or rehabilitation of severely deteriorated, unsafe, or improperly functioning components, (2) implementation of an effective ongoing maintenance program tailored to the specific corrosion and deterioration problems at APG-EA, and (3) recommendations to ensure that new construction is performed in accordance with current Army standards and guidance.

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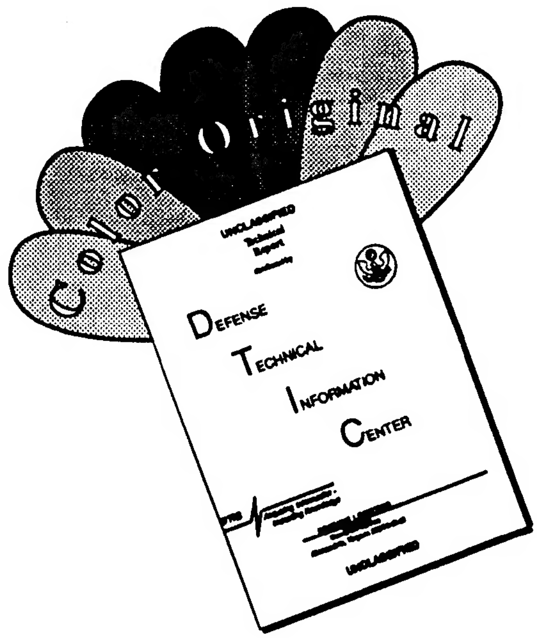

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave Blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	May 1995	Final

4. TITLE AND SUBTITLE
Thermal Energy Supply Optimization for Aberdeen Proving Ground - Edgewood Area: Distribution System Condition Assessment and Recommendations for Maintenance and Repair

5. FUNDING NUMBERS
MIPR
93-10

6. AUTHOR(S)
Vicki L. Van Blaricum, Charles P. Marsh, and Vincent F. Hock

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Construction Engineering Research Laboratories (USACERL)
P.O. Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
TR 95/02

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Aberdeen Proving Ground
ATTN: USAAPG/STEAP-FE-PE
Bldg 5252
APG MD 21005-5001

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

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14. SUBJECT TERMS
Aberdeen Proving Ground
steam heat distribution system
maintenance and repair

15. NUMBER OF PAGES
240

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

Foreword

This study was conducted for Aberdeen Proving Ground under Military Interdepartmental Purchase Request (MIPR) No. 93-10; Work Unit 93-10, "Corrosion Survey at APG." The technical monitor was Shehreyar Husain, USAAPG/STEAP-FE-PE.

The work was performed by the Engineering Division (FL-E) and Materials Science and Technology Division (FL-M) of the Facilities Technology Laboratory (FL), U.S. Army Construction Engineering Research Laboratories (USACERL). Larry M. Windingland is Acting Chief, CECER-FL-E, Ellen G. Segan is Acting Chief, CECER-FL-M, Donald F. Fornier, Jr. is Acting Operations Chief, CECER-FL, and Alvin Smith is Acting Chief, CECER-FL. The USACERL technical editor was Gordon L. Cohen, Information Management Office.

COL James T. Scott is Commander and Acting Director of USACERL, and Dr. Michael J. O'Connor is Technical Director.

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1 Introduction

Background

The Directorate of Public Works at Aberdeen Proving Ground (APG), MD, required technical assistance to address two major problems with part of its steam heat distribution system: (1) inadequate system capacity and (2) system deterioration. The affected portion of the system was located in APG's Edgewood Area (EA). The U.S. Army Construction Engineering Research Laboratories (USACERL), which conducts ongoing research in maintenance management, corrosion, and energy distribution, was contracted by APG to analyze the capacity and deterioration status of the EA steam distribution system.

The first problem—system capacity—was addressed through research conducted by the Utilities Division of USACERL's Utilities and Industrial Operations Laboratory. That research is documented in USACERL Technical Report 95/01, *Thermal Energy Supply Optimization for Edgewood Area, U.S. Army Aberdeen Proving Ground: Energy Supply Alternatives* (McCammon and Savoie, May 1995).

The second problem—system deterioration—arises from the fact that much of the EA heat distribution system is 40 to 50 years old. Many corrosion-related problems and other system deficiencies have developed in recent years. Such problems are evident even along newer (less than 15 years old) sections of the system. The result has been large energy losses and significant repair costs. Reductions in the maintenance staff and budget at APG have contributed further to the problem. Some areas of the system are beyond repair and must be replaced. The life expectancy and thermal efficiency of other areas of the system could be extended with minor repairs and the application of corrosion-mitigation techniques. Therefore, strategies are needed for the maintenance and repair (M&R) of existing system deficiencies and the mitigation of ongoing corrosion and deterioration problems.

Objectives

The objectives of this research were to

1. assess the condition of the heat distribution system at Edgewood Area
2. assess factors that have impacted the deterioration of the system
3. provide APG/EA recommendations for repairing existing deficiencies and mitigating ongoing corrosion and deterioration problems.

Approach

A physical inventory of the steam distribution system piping and manholes was conducted. An overall inspection and condition assessment procedure for steam distribution systems was compiled, and a significant portion of the distribution piping and manholes was assessed according to the procedure. Factors that impact the deterioration of distribution systems—including soil chemistry, cathodic protection, and chemistry of the products conveyed—were investigated and documented for Edgewood Area. Finally, recommendations for system repair and upgrade were documented.

Mode of Technology Transfer

The inspection and assessment methodologies compiled for this research will be refined and incorporated into a Fiscal Year 1995 AT41 work unit, "Integrated Strategic Utility Distribution System." An objective of this work unit will be to develop an Engineered Management System for utility distribution systems.

Metric Conversion Factors

U.S. standard units of measure are used in this report. A list of metric (SI) conversion factors is included below for convenience.

1 in.	=	25.4 mm
1 ft	=	0.305 m
1 lb	=	0.453 kg
1 mil	=	0.025 mm
1 psi	=	6.89 kPa
1 sq in.	=	6.451 cm^2
°F	=	(°C x 1.8) +32

2 Deterioration and Failure Mechanisms in Heat Distribution Systems

Overview

To maximize the efficiency and longevity of a heat distribution system, it is essential for both the designer and the operator to understand the deterioration and failure mechanisms involved, and their causes. With such an understanding, problems can be avoided or minimized. Scarce M&R resources can be allocated to remedy the root causes instead of making *ad hoc* stopgap fixes. This is especially important when a widespread renovation or replacement is planned, such as the proposed projects at EA. Even a newly installed system is a candidate for premature failure if attention is not given to all of the factors that can cause system deterioration.

Heat distribution systems are extremely vulnerable to deterioration and premature failure due to corrosion. The high temperatures and water present in such systems tend to accelerate most deterioration mechanisms. Systems that use buried steel conduit are especially vulnerable because they have four surfaces that can be exposed to aggressive environments. The inside surface of carrier pipes can be corroded by the products conveyed (especially condensate). With the ingress of water, the outside surface of the carrier pipes and the inside surface of steel conduits and casings can be corroded by aggressive aqueous solutions leached from the insulation. In addition, steam is often produced in the annular space, which greatly promotes degradation of the metal and the insulation. The outside surface of underground steel conduits can be corroded rapidly by aggressive soils. The outside surfaces of aboveground systems are not exposed to aggressive soils, but they are subject to precipitation, condensation, and other atmospheric factors that cause deterioration. Each of these mechanisms must be considered when performing an assessment of a heat distribution system and making recommendations for maintenance and repair.

This chapter presents basic background knowledge about the failure mechanisms involved in heat distribution systems. Factors promoting these failure mechanisms were thoroughly investigated during this research. The recommended action plan considers all of these factors in the remediation of existing problems and the avoidance of future ones.

Corrosion of Carrier Pipes by the Products Conveyed

Internal corrosion of steam and high-temperature hot water pipes is generally not a problem because the water in these lines is usually treated with anti-corrosion chemicals (Myers et al. 1991, pp 8-9). However, carbon steel condensate carrier pipes are vulnerable to serious internal corrosion and pitting if the condensate contains harmful levels of dissolved carbon dioxide or oxygen. Typically, corrosion due to dissolved carbon dioxide appears as "grooving" along the bottom interior surfaces of the carrier pipe. Corrosion due to dissolved oxygen appears as pitting. Dissolved gases typically enter the system in the boiler feedwater or through leaks in the system. Condensate return lines have been known to fail in as little as 1 year due to internal corrosion. Therefore it is very important to ensure that the boiler water is properly treated to mitigate this serious problem.

According to a recent study (Myers et al., July 1991), the corrosion rate (in mils per year [mpy]) for carbon steel condensate return lines can be estimated using the following expression:

$$CR = 3.7\,(CO_2 \times V)^{0.6} + 8.6\,(O_2 - 0.4)^{0.9} \qquad \text{[Eq 1]}$$

where CR = corrosion rate (mpy)
CO_2 = dissolved carbon dioxide content of the condensate, in ppm by weight
O_2 = dissolved oxygen content of the condensate, in ppm by weight
V = condensate flow rate (ft/min).

Fiberglass-reinforced plastic (FRP) condensate return lines do not corrode in the usual sense, but they are subject to damage (failure) from live steam, which may enter the lines when steam traps fail in the open position. Depending on the resin used, reinforced fiberglass piping can tolerate continuous-use temperatures for condensate that range from 190 °F to 250 °F. However, the impingement of live steam will very quickly cause a failure in any FRP piping.

Corrosion of Carrier Pipes and Conduits by Insulation-Related Leachates

Although moisture should not normally exist in the annulus between the carrier pipes and the conduits, wet insulation is a relatively common occurrence in Army heat distribution systems. A number of sources can contribute to wet insulation, including:

1. rain or condensation absorbed by the insulation during unprotected storage before installation

2. leaks in conduit joints that allow groundwater to collect inside the annulus
3. leaks in the carrier pipes that allow the conveyed product to collect in the annulus
4. leaks in the conduits (caused by aggressive soils) that allow groundwater to collect in the annulus.

Moisture in the annulus between the carrier pipe and the conduit can lead to deterioration or "boiling" of the insulation. Species that are aggressive to carbon steel (such as chlorides and sulfates) can be leached from certain insulation. All of these situations lead to accelerated corrosion and system leaks. In addition, if moisture is allowed to accumulate in the annular space, the system will lose thermal efficiency as the insulation becomes saturated and deteriorates. This results in wasted dollars and fuel resources.

It is therefore important during the operation and maintenance of heat distribution systems to ensure that the system remains dry. For the preapproved drainable-dryable systems (i.e., RicWil™ type) this involves a number of aspects covered in the piping manufacturer's maintenance brochure. To maintain the piping insulation integrity and effectiveness, a timely response to any tell-tale steaming from vents is essential. Otherwise, the insulation will be damaged and remain so for the rest of the system's useful life. Two useful diagnostic methods involve conduit air pressure tests and checking for water at the conduit drain.

By removing the drain plug at the low point of the section the presence of water in the conduit can be determined. For safety's sake, if there is any steam coming from either vent, that segment should first be deactivated and isolated before opening the drain. Replacing the plug is important to guard against water from the manhole getting into the conduit. In addition, the use of brass plugs allows for easy removal. Steel plugs corrode over time and tend to become very difficult to remove.

The conduit air pressure test is used to test the integrity of the casing against the ingress of ground water. The conduit is sealed and is then pressurized to 15 pounds per square inch (psi) with a pressure gauge attached. If the pressure decreases there is a breach in the conduit.

For nonmetallic conduits other types of damage can occur due to moisture in the annulus. In the case of FRP conduits the presence of steam in the annular space can cause severe damage. For older terra cotta conduit systems whatever joint sealant material was used, if any, could be damaged.

Corrosion of Metallic Conduits by Soil

Table 1 shows the likelihood of corrosion of carbon steel in soils of various resistivity. It can be seen that soils having resistivities less than about 10,000 ohm-cm are corrosive to carbon steel. To guard against corrosion, underground steel conduits should be coated and cathodically protected, or else nonmetallic conduits (such as concrete shallow trench systems) should be used. Army guidance requires that underground heat distribution piping in ferrous metallic conduit is to be cathodically protected in soils with resistivity of 30,000 ohm-cm and less (ETL 1110-3-440).

When systems are cathodically protected, it is important that the protected system be electrically isolated from other underground metallic structures. Otherwise, the intended corrosion protection could be rendered ineffective. For piping, electrical isolation is achieved by the use of isolation flange kits that consist of a gasket, with nonmetallic washers and bolt sleeves for every bolt. It is important to be sure that the materials are rated for the service temperature intended, that the flange kit is installed according to the manufacturer's instructions using a torque wrench, and that the bolts are re-torqued after the system is energized.

Degradation of Terra Cotta Conduit Systems

Although terra cotta conduit systems are not subject to soil-induced corrosion, they are subject to deterioration. For example, in a 50-year-old system such as the one at Edgewood, it is almost certain that the insulation has "slumped" off of much of the carrier pipe and lost most of its effectiveness. In addition, through ground settlement and low-intensity erosion from subsurface water movement, any conduit joint sealant materials that might have been in place are almost certain to have now been compromised. Water infiltration at the manholes is also likely.

Degradation of Aboveground Distribution Systems

Aboveground heat distribution systems are generally not exposed to as much moisture as buried systems, so they usually endure well. However, it is still possible for the aluminum sheathing and insulation to deteriorate over time and, in some cases, fall off the pipe entirely. This exposes the carrier pipe to corrosion and

Table 1. Anticipated corrosion activity for steel exposed to soils of varying resistivity.

Soil Resistivity Range (ohm-cm)	Corrosion Activity
0 - 2,000	Severe
2,000 - 10,000	Moderate
10,000 - 30,000	Mild
> 30,000	Slight

avoidable excess heat loss. The internal corrosion of aboveground condensate carrier piping is still as much of a concern as in buried systems, as noted earlier in this chapter. Other components of the system, such as pipe supports and guide cables, are subject to deterioration. In addition, the coatings on support poles tend to deteriorate over time.

Development of a Plan to Maximize Heat Distribution System Performance

Maximizing the performance of a heat distribution system involves three main objectives:

1. replacement or rehabilitation of severely deteriorated, unsafe, or improperly functioning system components
2. execution of a good maintenance program that is tailored to correct the specific corrosion and deterioration problems at the installation
3. making sure that any system replacements or new systems are specified and installed in accordance with current standards and guidance.

Determining the best course of action for accomplishing these objectives involve (1) performing a physical condition survey of the system and (2) collecting data about the factors that lead to deterioration and failure of the system. From this information, recommendations for replacement, renovation, correction of problems, and system maintenance can be formulated and prioritized.

3 Field Survey

Edgewood System Description

The study area included the steam distribution and condensate return piping that serves the 3000, 4000, and 5000 areas of the Edgewood Area at Aberdeen Proving Ground. Maps of these areas are shown in Appendix A. These maps have not been revised since the mid-1970s. Maps were reviewed with installation personnel to determine where lines have been shut off, removed, and added since then. There is currently a large project underway at APG to update all of the utility maps and store them electronically on a geographic information system (GIS).

To make identification and discussion of individual pipes in the distribution system more convenient, a naming scheme was devised based upon node numbers and the building numbers that were used for identification in the energy analysis of the system (McCammon and Savoie, May 1995). Each pipe section was identified by the nodes or buildings at its end points. For example, a section of pipe running from node 37A to Building 3835 was given the name 37A-3835. In addition, the manholes have been numbered to facilitate identification. Node, building, pipe section, and manhole identifications are shown in detail on the maps in Appendix A. All of the identification information, along with data for each pipe section and manhole, has been input into a spreadsheet program. This inventory spreadsheet document will be a "living" document for APG personnel, and will be extremely helpful in organizing information as various sections of the system are replaced and new ones are added. The current inventory spreadsheet is shown in Appendix B.

High-pressure steam (350 psi) in the Edgewood area is supplied by a waste-to-energy incinerator operated by a private company, Waste Energy Partners. The line from this incinerator plant is owned and maintained by Waste Energy Partners. The output from this plant varies with the moisture content of the waste being burned and is insufficient to supply EA's full load. The variability and the balance of the installation's requirements is supplied from four boiler plants owned and maintained by the government. One plant (E3312) supplies the 3000 area, two plants (E4225 and E4160) supply the 4000 area, and one plant (E5126) supplies the 5000 area. The current "take or pay" contract makes it advisable for the installation to use all of the outside steam

supplied. However, if the waste-to-energy plant were to go off-line, there is more than enough capacity available to provide heat during extended cold periods.

Several different designs and types of insulated piping are used to convey steam from the boiler plants to the individual building equipment rooms. The following discussion represents a combination of information from the utility maps and information provided by APG Engineering Plans and Services (EP&S) and Operations and Maintenance (O&M) personnel.

In the 3000 area, most of the piping is above ground, and consists of insulated (typically asbestos) and aluminum-cased steel piping mounted on steel poles, concrete piers, or wood trestles. This piping was installed about 1940, so it is more than 50 years old. In recent years, several new sections of piping have been installed. In 1991 a new aboveground line (section 35K-3649) was installed from the line serving Bldg E3560 to Bldg E3549.

Several sections of underground piping are installed in the 3000 area. There are several sections in the area of and interconnecting Bldgs E3220, E3224, and E3226 (sections 32E-3220, 3220-3224, and 3224-3226). These sections presumably consist of steel piping and insulation contained in a full round tile conduit, installed in approximately 1940. An underground line (section 30A-3081) was installed in about 1984 to service Bldg E3081, and an underground line (section 37A-3835) was installed in 1990 to service a new building—Bldg E3835. Both lines are a prefabricated underground conduit system consisting of distribution piping surrounded by mineral wool (or possibly calcium silicate) insulation and contained in a steel casing. The steel casing is coated with a thick coal tar-type material. These are the only lines of this type at EA.

In the 4000 area, all of the piping is underground with the exception of a short aboveground section, installed in 1992, near the boiler plant E4225. The original system in the area serviced by boiler plant E4160 was reportedly installed in about 1940 and is, therefore, more than 50 years old. The original system in the area serviced by boiler plant E4225 was reportedly installed in the early 1960s and is, therefore, approximately 30 years old. The original piping in both areas consists of steel piping and insulation (typically asbestos) contained in a full round tile conduit. This type of system is not pressure-testable. Several sections of the system in the 4000 area have been replaced in recent years. In the area serviced by plant E4160, a new line was installed from the plant to Bldg E4810 (section 4160-4810) in 1991. New lines were installed from the main line to Bldg E4140 (section 44D-4140) and from the main line to E4620 (section 44F-4620) in 1991. These three lines consist of direct-buried

steel pipe surrounded by Protexulate™* with no casing. The piping in the area of Bldgs E4221, E4222, E4224, E4227, E4228, and E4229 (sections 42A-4221, 42A-4229, 42B-4227, 42C-4228, 42D-4224, 42E-4223, and 42F-4222) was reportedly replaced sometime between 1986 and 1988. It is presumed that the same materials were used here as in the other areas replaced in the 4000 area, namely direct-buried steel pipe surrounded by Protexulate with no casing. In the area serviced by E4225, pipes serving Bldgs E4210, E4215, and E4220 (sections 42M-4210, 42M-42N, 42N-4215, and 42N-4220) were reportedly replaced in 1992 with steel pipe wrapped with insulation and surrounded by Protexulate. It should be noted that Protexulate is not approved by the Federal Agency Committee (FAC) as insulation for Class A sites. The approved insulations are listed in Corps of Engineers Guide Specification (CEGS) 02695 (May 1991).

In the 5000 area, there is a mixture of aboveground and underground piping. Portions of the system are shut off in the summer. The aboveground piping in the 5000 area consists of insulated (typically asbestos) and aluminum-cased steel piping mounted on steel poles, concrete piers, or wood trestles. Like much of the heat distribution system, this piping is more than 50 years old. Exceptions are the new aboveground piping installed in 1992 to Bldg E5648 (section 56E-5648, and the new 4 in. line (section ID 56J-55A) installed from the 10 in. line near Bldg E5360 to the 4 in. line near Bldg E5560.

Much of the underground piping in the 5000 area was installed in the 1940s and consists of steel piping and insulation (typically asbestos) contained in a full round tile conduit. New sections have been added, and sections have been replaced with a variety of materials and configurations. A new 10 in. line (section 56F-56G) was installed from Bldg E5330 to the 8 in. line. Piping to Bldgs E5100, E5106, E5103, and E5116 was replaced with steel wrapped with plain fiberglass insulation and a vapor barrier. This area is scheduled for another replacement. The lines to Bldgs E5026, E5027, and E5180 (sections 51LA-51P, 51P-5026, and 51P-5027) were replaced around 1980 with steel pipe surrounded by WYECOR, which is a mixture of concrete and recycled tires. A section of the 8 in. underground line near Bldg E5330 (section 56F-56FB) was also replaced with steel pipe surrounded by WYECOR at about the same time. A portion of this line (section 56F-56FC) has recently been replaced with a steel line surrounded by fiberglass insulation and Protexulate.

In addition, a network of fiberglass condensate return lines was constructed in about 1987 in the 5000 area.

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* Protexulate™ (also called DriTherm™) is a calcium carbonate insulation that has a white, powdery appearance.

Leak/Problem History

Interviews were conducted with personnel from the EP&S Division and the O&M Division to obtain background information on leak/maintenance history. The installation has no written records of leak and maintenance history.

The biggest problem identified by all APG personnel interviewed was the severe corrosion of condensate lines. They reported problems with condensate lines in the buildings as well as in the distribution system itself. Personnel reported that when a condensate line fails, there is typically "a grooved area in the bottom that is paper-thin." The condensate line from boiler plant E3312 to the 3700 area (section 3312-37A) was reported to be in particularly poor condition. Failures were also reported with the relatively new FRP return lines in the 5000 area. Personnel noted that there is no way to shut sections of the fiberglass line down for repairs without taking down the whole system.

Another problem noted was that condensate is not being returned from many buildings. This problem was noted for the following buildings: E-3300, E-3324, E-3370, E-3525, E-3542, E-3550, E-3570, E-3720, E-3724, E-3725, E-3726, E-3728, E-5140, E-5188, E-5244, E-5266, E-5307, E-5352, E-5354, E-5422, E-5425, E-5427, E-5441, E-5452 , E-5554, E-5560, and E-5641.

Personnel reported that the steam lines were basically in "good shape" with the exception of a few problem areas. The underground sections installed with WYECOR were identified as serious problems. In fact, as noted above, part of one of the sections cast in WYECOR has already been replaced. Other problem areas reported included the lines located in front of building 1570, the entire 4400 area, the line from boiler plant E5126 to E5100 (section 5126-51A), and the line near Bldg 5360. Personnel reported that the aboveground line from E5360 to the 5400 area (section ID 54D-54A) was in poor condition. Although the line in front of Bldg 1570 was not included in the study area, it was investigated because it has failed and been replaced four times within the last 10 years.

Personnel reported that the prefabricated conduit-type systems installed in Bldg 3081 and Bldg 3835 (sections 30A-3081 and 37A-3835) have been performing well. The only deficiency they noted was the difficulty in drainage of condensate on the line to Bldg 3835 (probably mistakenly caused during installation).

It was also reported that all replacements in the past 4 or 5 years have been made with steel pipe covered with fiberglass insulation and surrounded by Protexulate.

Aboveground System Condition Survey

A visual condition assessment of a significant percentage of the aboveground distribution system was conducted. This included examination and videotaping of the aboveground lines. During the visual condition assessment, the condition of aboveground lines was rated as good (G), fair (F), or poor (P). Lines were classified to be in good condition if no deficiencies were noted and no repairs were required. Lines were classified to be in fair condition if minor deficiencies (such as missing insulation) were noted. Lines were classified to be in poor condition if major deficiencies (such as leaks or severe steaming) were noted. Lines in poor condition were typically recommended for replacement. The lines were checked for the following deficiencies:

- deterioration of casing
- missing, wet, or otherwise damaged insulation
- leaks
- leaking valves or flanges
- areas of steaming
- deterioration of supports, including rusting, bending, failed coating, failure of the pipe to rest on the support, or other deterioration which affects functionality and/or safety
- corroded or "slack" support wires
- vegetation around lines.

Significant observations are summarized here. Detailed observations are documented in Appendix C.

In the Edgewood area, much of the aboveground piping is still in good condition. In many places, though, the aluminum sheathing and insulation have fallen off, exposing the carrier pipe to external corrosion and avoidable excess heat loss. Figure 1 shows an example of this condition on the condensate line section 3312-37A near Bldg E3370. In this particular instance, it was noted that the insulation was asbestos.

An estimated 2,000 ft of aboveground piping, ranging from 2 to 6 in. in diameter, was found to be without insulation. In addition, there are numerous sections (such as that shown in Figure 1) where insulation and insulation covering are damaged. Missing insulation is particularly a problem at pipe elbows. Figure 2 shows an example of this.

Many of the metal support poles are in need of recoating. Figure 3 shows a typical example of deteriorated coating on support poles. An important issue here is the possible presence of lead-based paint. Testing on one of the poles supporting the aboveground piping indicated the presence of lead. One test does not provide enough

Figure 1. Deteriorated insulation on section 3312-37A near Bldg E3370.

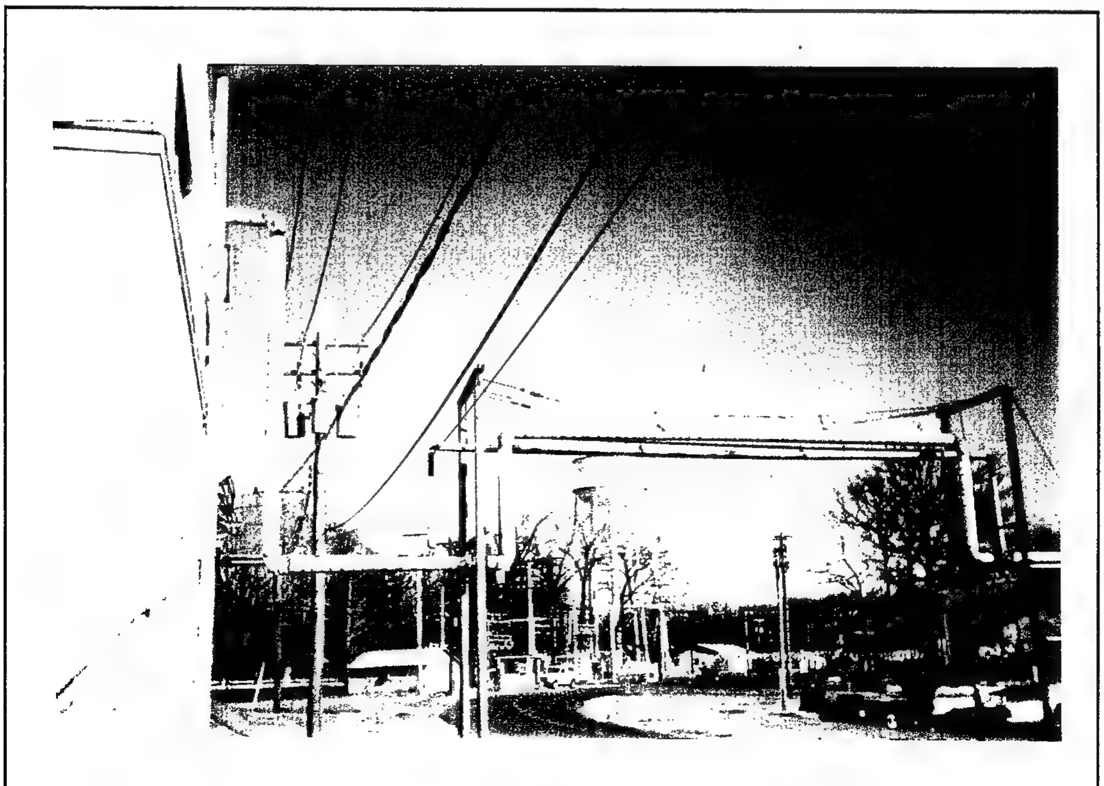

Figure 2. Typical example of missing insulation on pipe elbows near Bldg E3312.

data from which to draw conclusions, but it is important to be aware of the possibility that lead-based paint might be present when maintenance is performed or coated components are replaced or demolished. Recommendations pertaining to managing lead-based paint can be found in Chapter 4 under "Recommendations."

Figure 3. Typical example of deteriorated coating on support pole near Bldg E3312.

Aboveground piping anchors consisted of steel guy wires extending from the pipe to ground-level concrete piers. Several of these wires were broken or detached and others were severely corroded. Some of the wires and guide cables were slack and were not performing their intended function. Failure of anchors can cause unacceptable stresses in the system, possibly leading to pipe and fitting damage.

Many of the pipe guides and supports on the low profile aboveground lines were damaged and did not function as designed. Other locations were observed where "substitute" supports had been used. Figure 4 shows a location where a cloth strap was used to support a pipe. This practice should be discontinued. Figure 5 shows an example of a pipe that was not resting properly on support rollers. As noted above for piping anchors, this deficiency can result in unacceptable stresses and possible pipe or fitting damage.

The 4 in. condensate return line in the 3000 area extending from the boiler plant to near Bldg 3725 (section ID 3312-37A) was inspected in the area of Bldg 3370. The condensate line is severely corroded and is in extremely poor condition. Several leaks and areas of steaming were observed (Figure 6). Most of the leaks were along the top of the pipe. The insulation was badly deteriorated. Insulation was removed from the lines in several locations, and visual inspection revealed that the lines were corroding

Figure 4. Improper pipe support at Bldg TE3613.

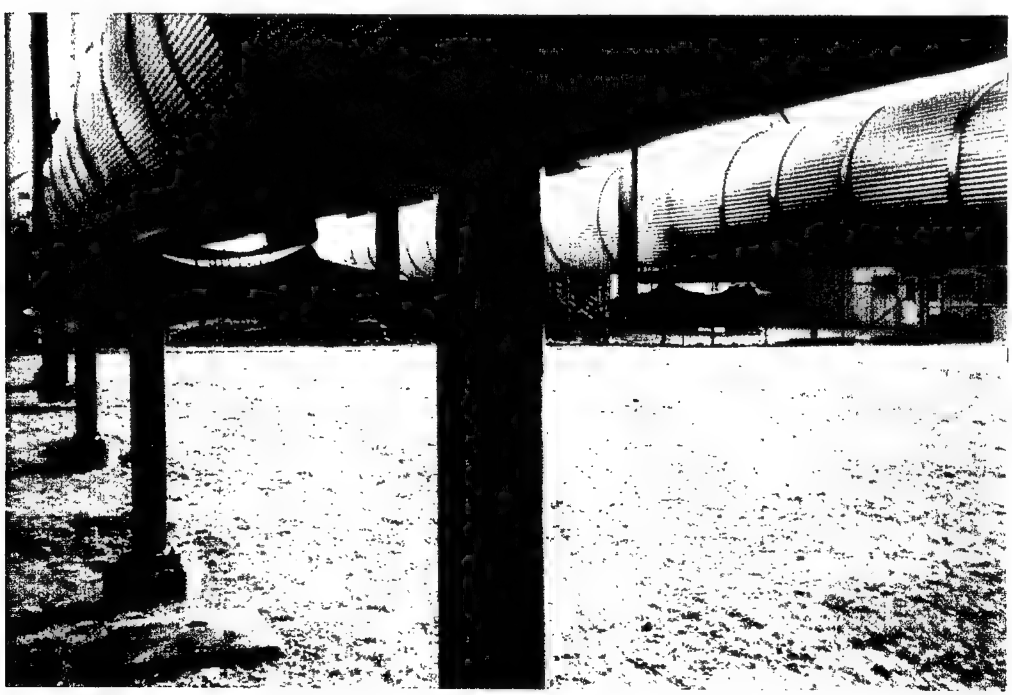

Figure 5. Typical example of pipe not resting properly on support rollers on line to Bldg E3570.

Figure 6. Condensate line leak near Bldg E3607.

from the outside. This observation was supported by the fact that most leaks were on the top area of the pipe. If corrosion was being caused by the condensate acting from the inside, most of the leaks would appear along the bottom of the pipe. Most likely, the severe corrosion along this section is due to wet insulation at the pipe surface. The steam lines were in fair condition. In addition, there was excessive vegetation, including several trees, growing between the steam and condensate line (Figure 7). This vegetation should be removed. Areas of missing insulation were also observed (Figure 8).

In some instances it was found that condensate was being dumped rather than being returned to the boiler plant. This practice, when combined with trap failure (Figure 9), dramatically reduces system efficiency. The extra costs come from having to replace the water and heat it from ambient temperature to the condensate return temperature. Further costs include the chemical treatment for the makeup water. Appendix D provides a simple method to estimate the potential savings associated with returning condensate (rather than dumping it).

Other defects observed were leaking flange gaskets (Figure 10) and leaking valve packing (Figure 11). These defects also cause significant heat loss. Figure 12 shows a condensate tank resting directly on the ground. Contact with the soil will accelerate the failure of this tank due to corrosion. In addition, Figure 12 shows a typical case of missing pipe insulation.

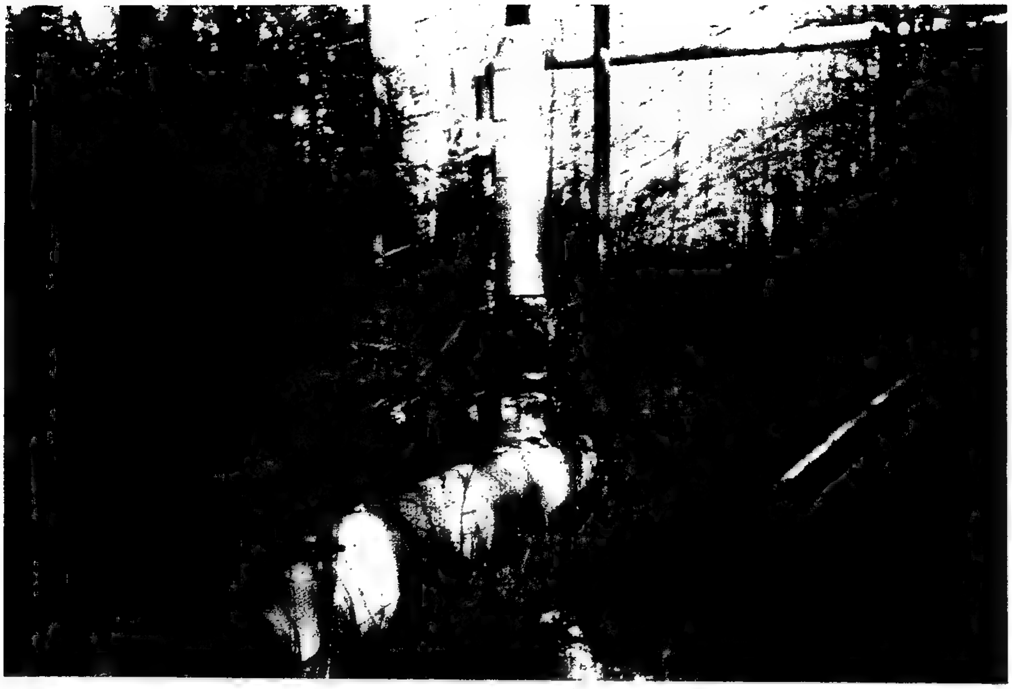

Figure 7. Excessive vegetation around and between lines on Section 3312-37A.

Figure 8. Trees growing between lines and missing insulation on pipe elbows on Section 3312-37A.

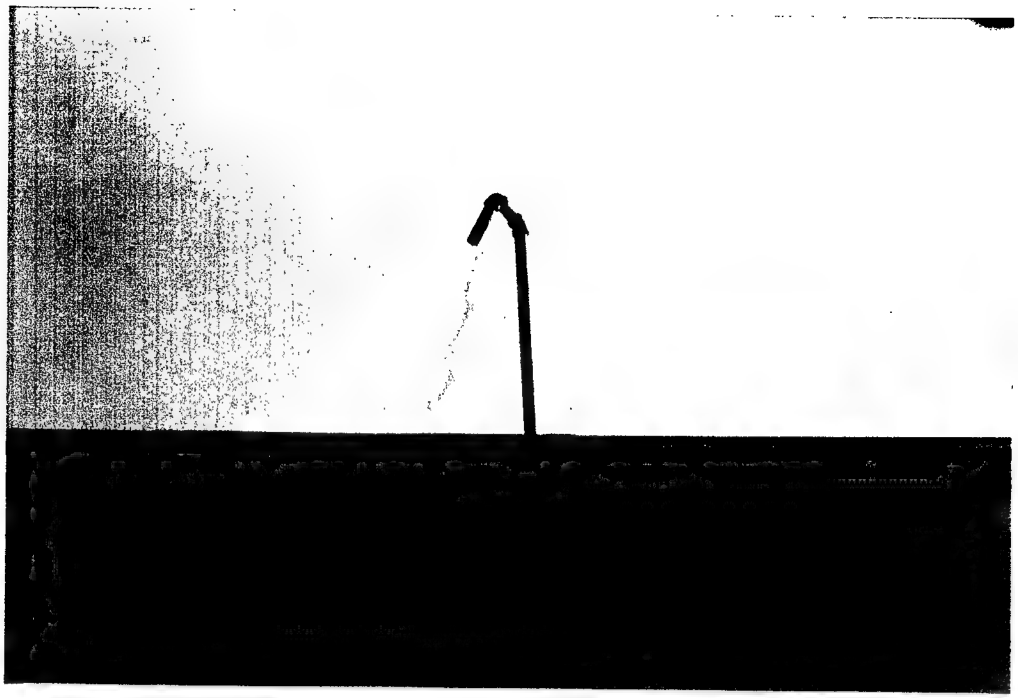

Figure 9. Failed steam trap at Bldg E3516, reportedly replaced 3 years ago.

Underground System Condition Survey

The low-lying terrain and various creek beds in the area that feed the Gunpowder River strongly suggest that Edgewood is a Class A site. This means that the water table is expected to be frequently above the bottom of the system or that surface water is expected to accumulate and remain for long periods in the soil surrounding the system. Appendix E consists of two tables, extracted from CEGS 02695, which describes in detail the process of site classification.

For the underground lines, the condition assessment involved a visual examination of the manholes and manhole internals in a significant number of the system manholes, as well as observation of the ground surface above the lines to note areas of dead grass or abnormally green grass (either of which can denote severe heat losses). Manholes were checked for the following deficiencies:

- standing water (or indication that there has been standing water)
- deterioration of manhole tops/covers (safety hazard)
- deterioration of access ladders (safety hazard)
- missing insulation on pipes
- leaking valves
- leaking or deteriorated gaskets

- deteriorated wall penetrations and evidence of water inflow
- corroded wall supports
- clogged drains
- steaming
- excessive debris
- lack of sump pumps.

Figure 10. Leaking flange gasket at junction between old and new system near 3300 area.

Significant observations are summarized here. Detailed observations noted during manhole inspections are given in Appendix C.

Most of the manholes at Edgewood appear originally to have been constructed of brick, with a masonry facing added later. These walls are approximately 6 in. thick. The floors, typically, are concrete with a French drain built in. This type of drain consists of crossed channels free of concrete where accumulated water is intended to drain into the soil. The walls were structurally supported internally with steel beams extending from wall to opposite wall. Manhole tops are generally constructed of prefabricated steel designed to sit on the top perimeter of the manhole. The tops are about 1 ft high with screened side panels for ventilation purposes and covered with solid steel plates. A moveable or hinged panel was provided for manhole access. Conduit vents were run to near the manhole top or were extended above grade. A number of problems were observed in the manholes surveyed.

There was a lack of insulation on most interior manhole piping and internals. A typical example is shown in Figure 13. This lack of insulation on the piping often extended back into sections of the full round tile conduit. In addition, pipes were observed where the insulation had "slumped" to the bottom of the conduit. It is likely that this condition existed along the entire run connected to the manhole where the slumping insulation was found—especially since many areas of the system are approximately 50 years old. In areas where the older full round tile conduit is

installed, the conduit runs and loops were generally outlined by dead grass immediately above the piping. This indicates excessive heat loss which is probably due to deterioration of the insulation inside the conduit. In the areas where the non-tile (i.e., metallic) casing was used, con siderable corrosion was observed on some of the conduit casings that extended into the manhole. These casings are much thinner than the end plates and can be a source of early system failure.

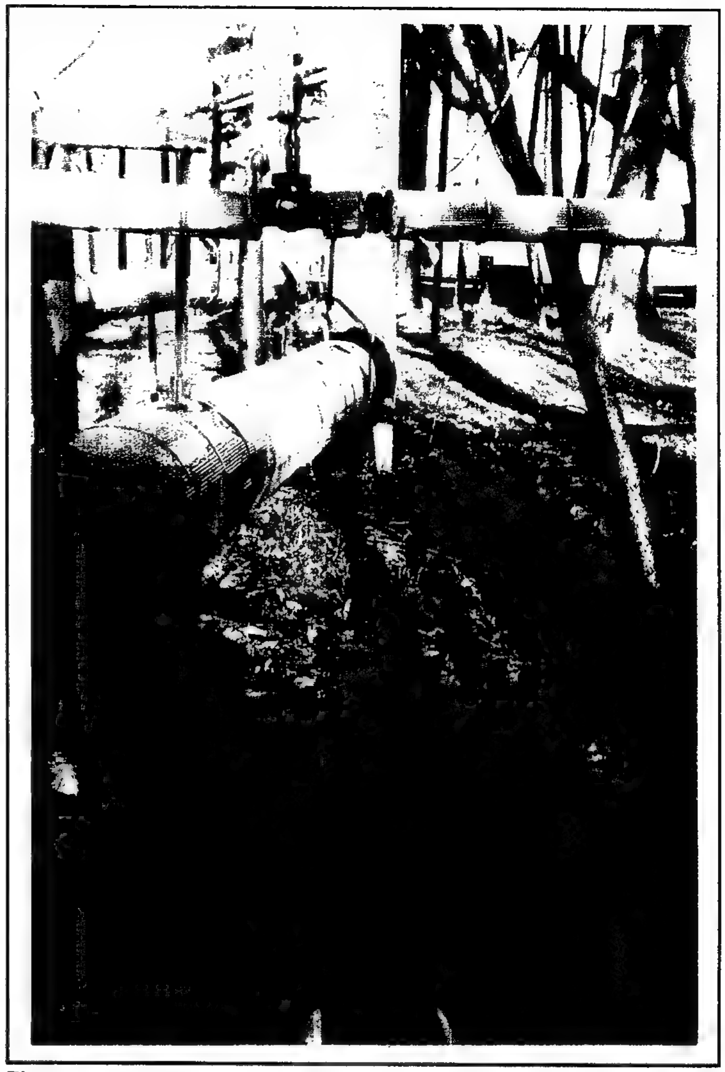

Figure 11. Leaking valve packing on 2 in. return line from Bldg E3580.

Many of the screens on the manhole tops are missing and should be replaced to prevent the manholes from collecting debris. Figure 13 shows an example of a manhole containing excessive debris. Such debris can prevent or severely impede the drainage of water from the manhole.

Strong evidence of standing water was observed in many of the manholes surveyed. Although many manholes were relatively dry at the time of this inspection, water marks on the manhole walls indicated that flooding is common. Water was observed in a few manholes, including the one shown in Figure 14. The pipes in this manhole are not insulated. The type of drain currently installed in the manholes often performs poorly. In addition, no sump pumps were found in any of the manholes surveyed. *The detrimental effect of standing water in manholes cannot be overemphasized.* The steam generated from standing water presents a significant safety hazard to maintenance personnel (Figure 15). Water, in combination with the high temperatures present, will accelerate corrosion of the manhole internals (Figure 16), and can cause accelerated failure of the casings and carrier pipes themselves.

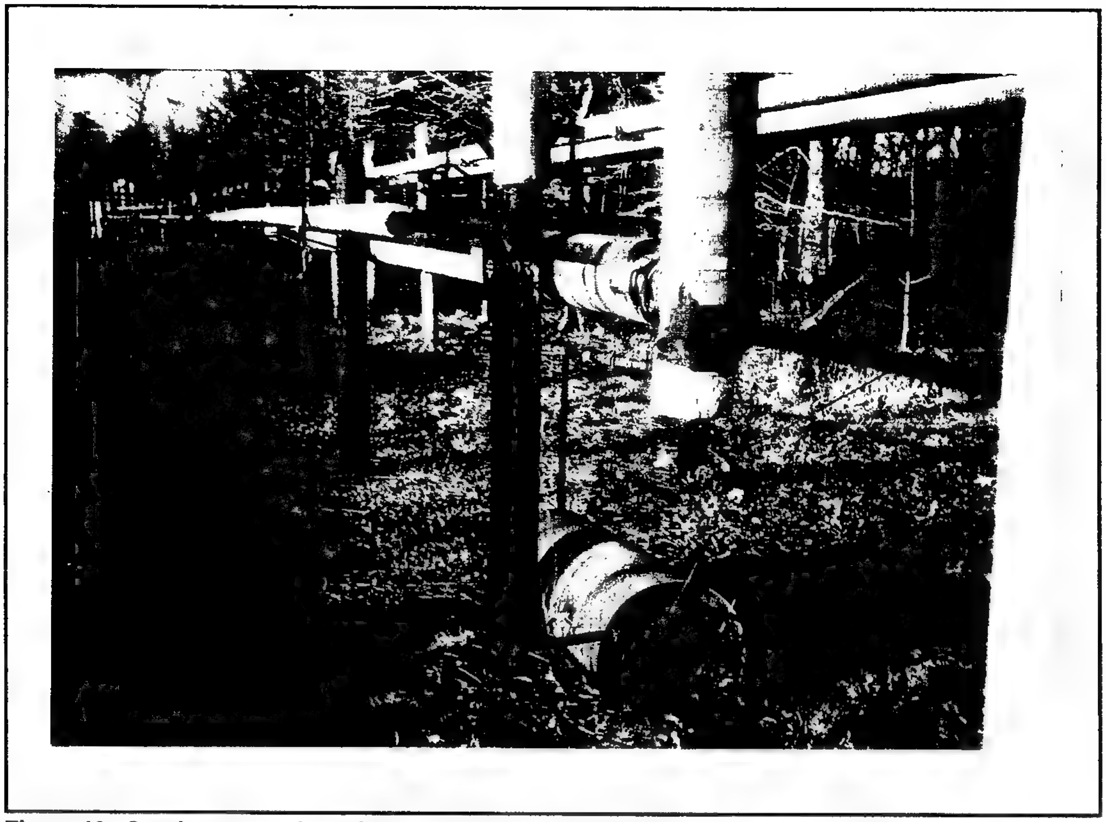

Figure 12. Condensate tank resting on the ground near Quonset huts in 3000 area, with insulation missing from pipe.

Figure 13. Typical example of excessive debris in manhole (no. 5320).

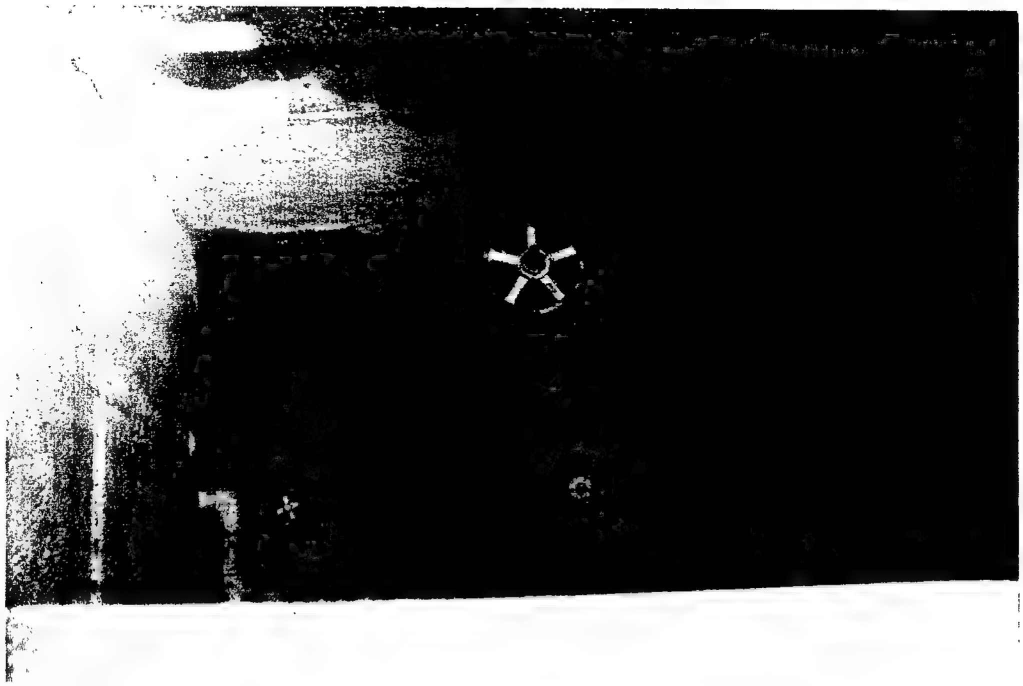

Figure 14. Typical manhole (near Bldg E1570) with standing water and uninsulated pipes.

Figure 15. Typical steaming manhole (no. 5220) with standing water.

Figure 16. Uninsulated and severely corroded pipes in manhole no. 5100.

Manhole wall penetrations involved the extension of conduits through slightly oversized holes that were caulked and cemented at the interior surface of the walls. Most of the caulking at conduit wall penetrations was dried and deteriorated. Figure 17 shows a severely deteriorated manhole penetration. The caulking could not prevent groundwater infiltration into the manhole. This problem may contribute significantly to the flooding problem discussed in the previous paragraph. Also note the severe corrosion of the pipe entering the ground in Figure 17. In this example there was no evidence of the current practice, which is to use a metallic wall sleeve with a flange water stop and link seals to prevent water entry. Another problem that was frequently observed was old manhole penetrations that had not been properly sealed (Figure 18). Improper sealing provides another route for groundwater infiltration into the manhole.

Pipe moment guides for expansion joints in manholes have failed due to corrosion, and no longer serve their purpose. Improper alignment at expansion joints can cause major damage. Slip-type expansion joints require a very accurate alignment to operate as intended. Misalignment can cause the pipe to bind in the expansion joint as it tries to expand. If not taken up in the slip joint, thermal expansion forces can cause severe damage elsewhere in the system. These joints also require periodic lubrication and repacking.

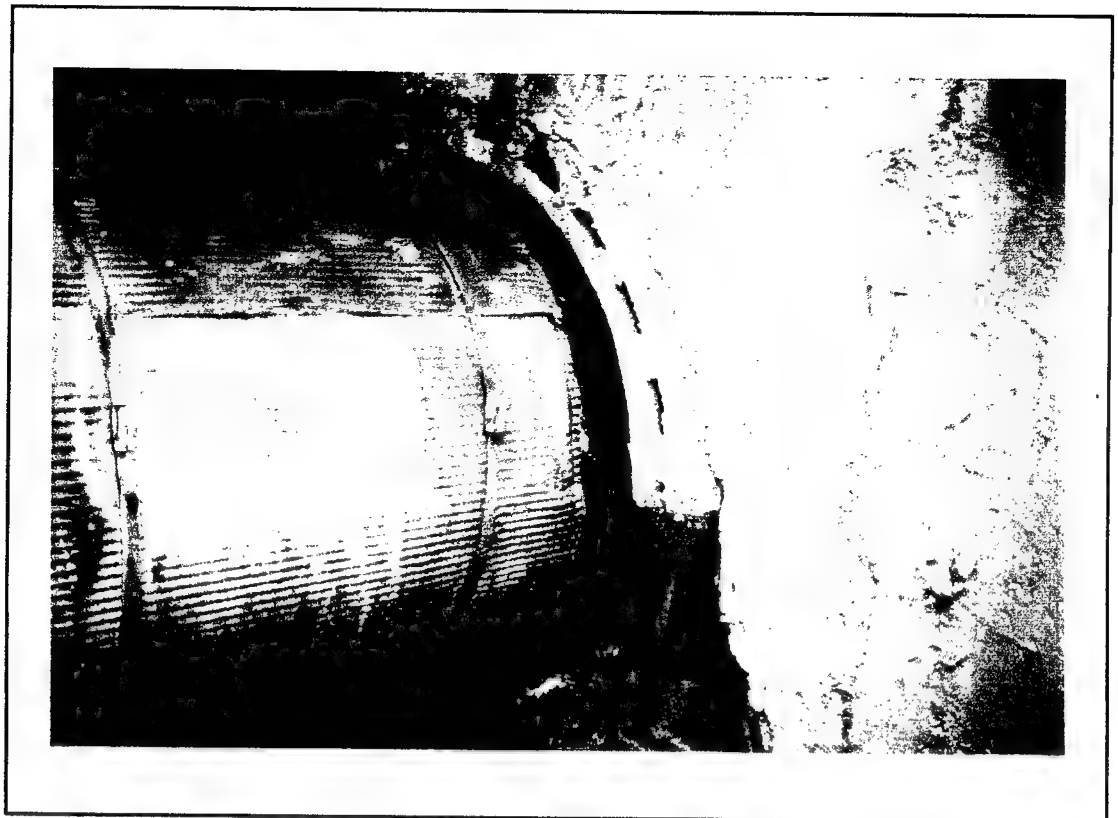

Figure 17. Typical deteriorated manhole wall penetration (no. 5100), with corrosion on pipe entering the ground.

Figure 18. Typical example of old unsealed manhole penetration.

Steel beams supporting manhole walls were heavily pitted and corroded (Figure 19), as are the inner surfaces of the steel plates on the manhole tops. Manhole walls are also deteriorating, with excessive spalling and cracking evident (Figure 20). These conditions may present a future safety problem.

In several manholes, the entry ladders were badly corroded and were not securely fastened to the manhole walls. In the interest of safety, these must be repaired.

Plugged vents were observed in some manholes (Figure 21). Steaming vents are one of the primary indicators of a leak or problem in the system. Plugging the vents eliminates this "early warning" mechanism. Furthermore, if the pipes are not properly vented, pressure can build up to unacceptable levels.

One manhole with an excessively heavy concrete manhole cover was observed (Figure 22). Such manhole covers make it very difficult to perform maintenance or inspections in the manhole.

Much of the underground heat distribution piping at Edgewood consists of a steel carrier pipe wrapped with asbestos insulation and protected by sections of 3/4 in. terra cotta conduit. In addition, a tar or tar paper, or bitumastic coating may have been used to seal the conduit joints. Because these systems are approximately 50 years old it is almost certain that the insulation has slumped off much of the carrier pipe, and consequently has lost most of its effectiveness. In addition, through ground settlement and low-intensity erosion from subsurface water movement, any conduit joint sealant materials that might have been in place are almost certain now to have been compromised. Neither of these situations can be known for certain without some exploratory excavation. However, dead grass is in evidence along many of the terra cotta conduit lines, indicating either a very shallow burial depth or excessive heat loss. To kill cool-season grasses with heat requires a steady temperature of 80-90 °F within 6 in. of the surface (Beard 1973). Although many of the variables involved are not known to great accuracy an attempt has been made to at least quantitatively bound the amount of heat loss (McCammon and Savoie, May 1995).

Bellhole Inspections

Bellhole inspections were conducted on the line to Bldg E3081 (section 30A-3081), the line in front of Bldg E1570, and the line to Bldg E3835 (section 37A-3835).

Section 30A-3081 was the prefabricated type, with a metal casing and heavy tar-type coating on the outside. The line was in good condition (Figure 23). Although the soil

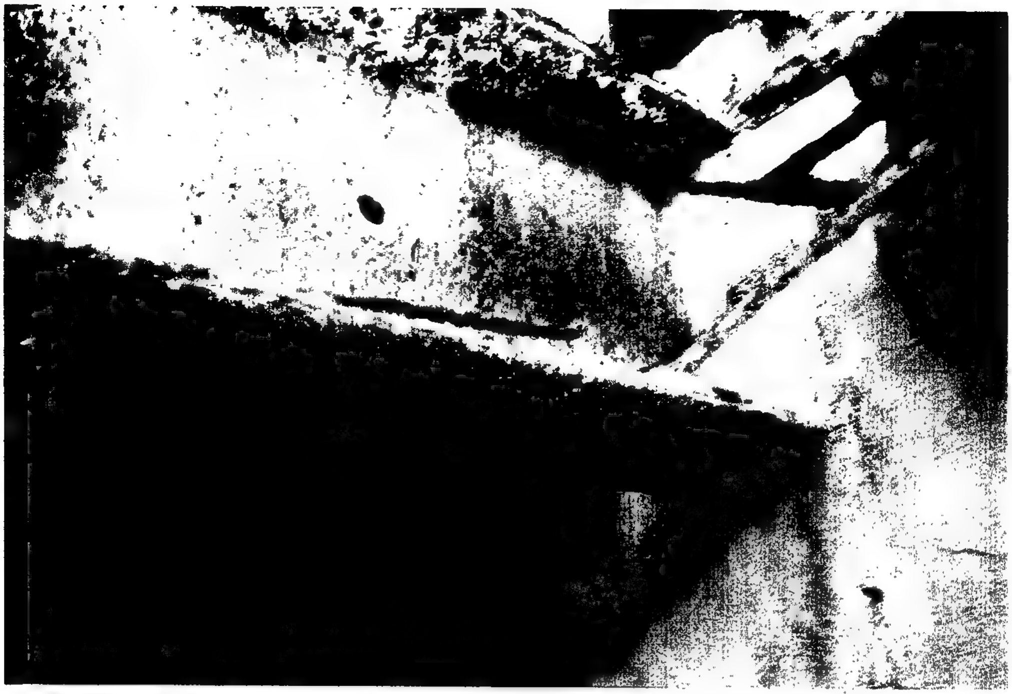

Figure 19. Typical example of corroded manhole support beams (no. 5100).

Figure 20. Corroded manhole support beams and cracking of manhole walls in manhole 4040.

Figure 21. Plugged vents in manhole no. 4040.

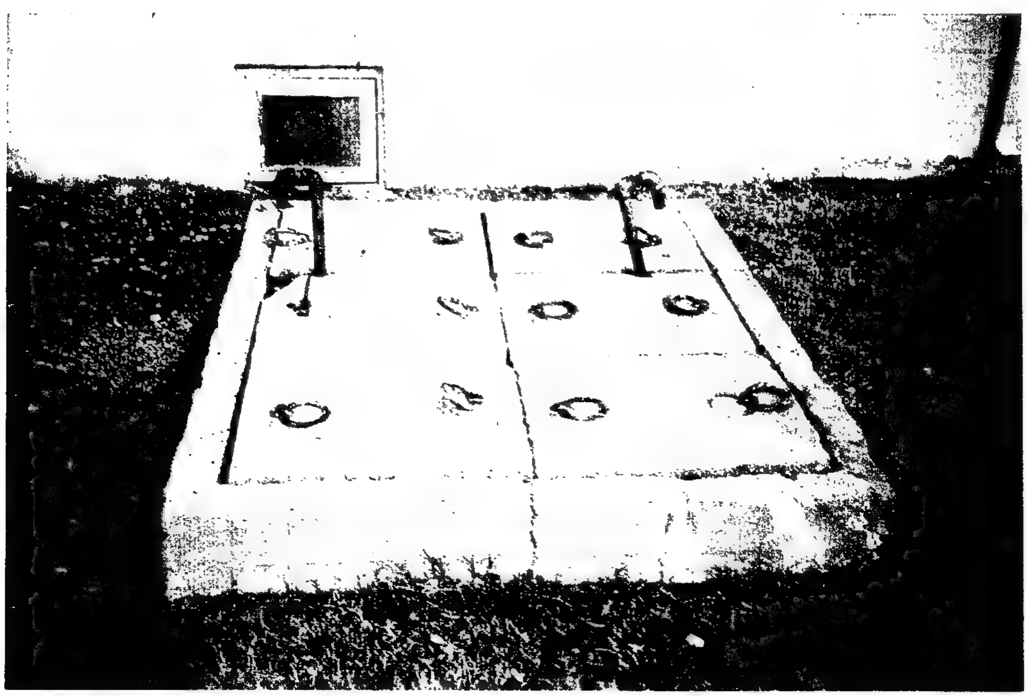

Figure 22. Excessively heavy concrete manhole cover in the 4000 area.

Figure 23. Six in. steam line to Bldg E3081 (Section 30A-3081), with coating and pipe both in good condition.

showed stratification, indicating possible differences in resistivity, the coating was intact and there were no visible corrosion pits.

The steam and condensate lines in front of Bldg E1570 were direct-buried steel surrounded by Protexulate. The corrosion pit depths on the steam line averaged approximately 0.01 to 0.02 in. (Figure 24). Corrosion pit depths on the condensate line measured less than 0.01 in. (Figure 25).

A bellhole inspection was attempted on section 37A-3835, but DPW personnel were unable to locate the line. A soil sample was taken from the excavation at a depth of approximately 5 ft. It was noted that the soil was steaming at the area where the soil sample was taken. This indicates that the piping is losing heat well in excess of design specifications.

Overall System Condition

From the standpoint of thermal efficiency and physical condition, the overall system is considered to be in fair to poor condition.

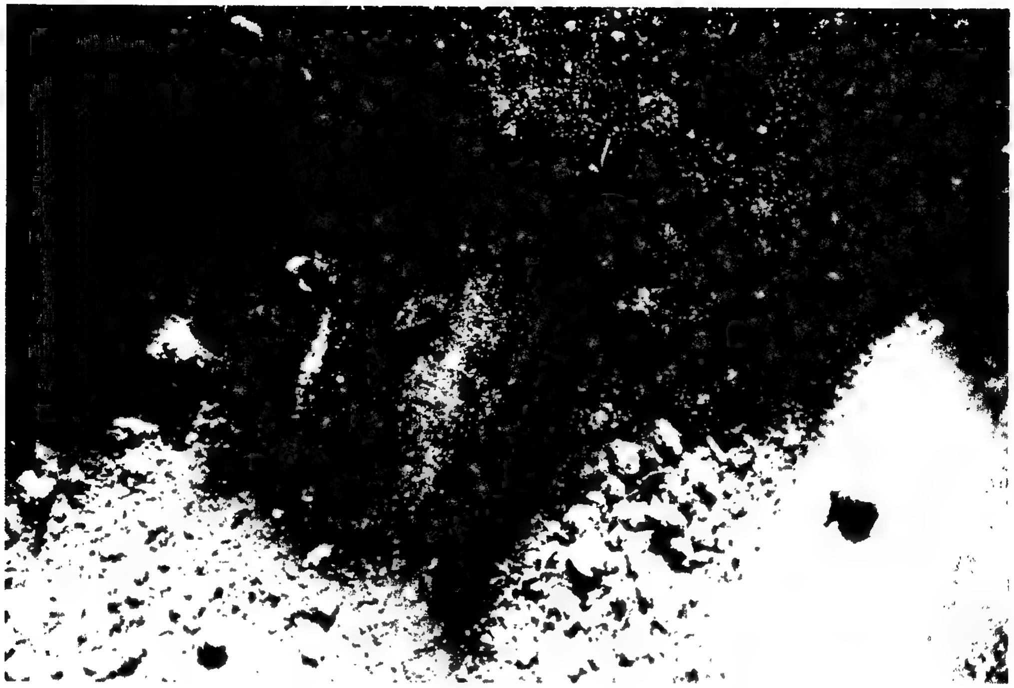

Figure 24. Steam line in front of Bldg E1570, with corrosion pit depths averaging 0.01 to 0.02 in.

Figure 25. Condensate line in front of Bldg E1570, with corrosion pit depths averaging less than 0.01 in.

Soil Testing

To determine the potential for soil-side corrosion of underground steam or condensate piping that has metallic casing in direct contact with the soil, data on the chemical composition of the soil were obtained at several locations throughout the area covered by the study.

Procedure for Field Evaluation of Resistivity

Extensive testing of the soil resistivity at Edgewood was conducted in 1977 by the Facilities Engineering Support Agency (FESA) (McLeod and Barthelmy 1977). Since soil characteristics typically do not vary appreciably over time, these resistivity measurements can be considered valid for the current work. The variations in resistivity at any given location are caused mostly by seasonal variations in soil moisture. Soil resistivity tends to decrease during especially wet periods, and tends to increase during especially dry periods.

Despite the availability of relevant soil resistivity data, several locations for resistivity measurements and soil sampling were selected based upon the general leak history information and casing material data given. The reason for this was to verify the accuracy of the 1977 measurements and to obtain additional soil chemistry data that affects the corrosion rate. Sampling locations were selected in the E3000, E4000, and E5000 areas. A location in the E1500 area was investigated because of severe, recurrent corrosion problems, even though it is outside the area covered by this study. Soil resistivity tests were conducted in the field at each sampling location according to ASTM Standard G57 (1992). The tests were conducted on 9-10 February 1993. Pin spacings for the tests were set depending on the depth of the buried lines as observed from adjacent manholes. Measurements were conducted using an Associated Research Model 293 Vibroground®.

Procedure for Laboratory Evaluation of Soil

Soil samples were collected for laboratory evaluation at six locations on 2 June 1993. Samples were obtained by augering down to the approximate pipeline depth and collecting a 1 to 2 liter sample in a plastic "ziplock" bag. The soils were tested in the laboratory to determine pH, resistivity, moisture content, sulfate content, sulfide content, and chloride content. Standards used for testing are listed in Table 2.

Table 2. Standards used for laboratory soil testing.

Analysis Description	Analysis Method
pH	EPA 9045
Resistivity	ASTM G57
Sulfate	EPA 9038
Sulfide	EPA 376.1
Chloride	EPA 9252
Moisture	EPA 160.3
Total Acidity	EPA 305.1

Soil Testing Results and Discussion

Results from the 1993 Wenner 4-pin soil resistivity tests conducted by USACERL are shown in Table 3. Results from the 1977 FESA soil resistivity tests are shown in Table 4. Results from laboratory testing of the soils are given in Table 5. The results are discussed in the following paragraphs.

Soil Resistivity

One of the most important factors affecting corrosion activity along an underground pipeline is the resistivity of the electrolyte (soil). Corrosiveness of the environment is generally an inverse function of resistivity. Low resistivity favors the flow of current and increases the probability of corrosion; corrosion may not be a problem in very high-resistivity electrolytes. The effect of soil resistivity on the anticipated corrosion activity for steel can be predicted using information given previously in Table 1. These data, however, should not be used as an absolute criterion for corrosivity. Often, severe corrosion damage occurs in soils having relatively high resistivities. This is especially true in heterogeneous soils (e.g., an environment of clay lumps mixed with sand).

Table 3. Wenner 4-pin soil resistivity data from 1993 USACERL survey.

Location	Pin Spacing (ft)	Resistivity (ohm-cm)	Anticipated Corrosion Activity
Bldg 1570	5	8235	Moderate
	10	3850	Moderate
Bldg 3081	2.5	4787	Moderate
	5.0	5745	Moderate
Bldg 3724	2.5	8618	Moderate
	5	7852	Moderate
Bldg 4445	5	5362	Moderate
	10	3064	Moderate
Bldg 5604 Alley & 34th	5	9575	Moderate
	10	10724	Mild
Bldg 5100	5	11490	Mild
	10	9192	Moderate
Bldg 5360	5	22981	Mild
	10	24896	Mild

Table 4. Wenner 4-pin soil resistivity data from 1977 survey.

No.	Location	Soil Resistivity With 5 Ft Pin Spacing (ohm-cm)	Soil Resistivity With 10 Ft Pin Spacing (ohm-cm)
1	E Bldg 5936	17240	22980
2	Bend on Redwing Rd	5650	6894
3	S Bldg 5915	8230	8809
4	S Bldg 5888	11490	17044
5	N Bldg 5848	29680	38300
6	N Lagoon Rd	6700	12830
7	E Bldg 5690	11490	18384
8	S Bldg 5672	9580	11490
9	N Bldg 5565	9000	4404
10	E Bldg 4836	6610	1915
11	S Bldg 4677	6890	5554
12	S Bldg 4730	3450	3830
13	W Bldg 4465	6030	6320
14	S Bldg 4162	11490	10532
15	S Bldg 5405	9580	8618
16	E Bldg 5330	3540	823
17	E Bldg 5633	9580	5554
18	S Bldg 5190	3540	3638
19	S Bldg 5707	9580	6702
20	N Bldg 5703	9580	6702
21	E Siebert Rd	3350	5362
22	N Bldg 5762	8430	5745
23	W Bldg 6659	10532	9766
24	N Bldg 6619	25852	34470
25	S Bldg 5185	4980	4404
26	W Bldg 5307	14360	13405
27	N Bldg 4486	3730	4022
28	E Bldg 4530	8230	12256
29	E Bldg 4420	3730	2872
30	NE Bldg 4410	7090	9000
31	N Bldg 5238	10530	12064
32	N Bldg 5033	5080	4979
33	S Bldg 1574	5080	2681
34	S Bldg 1570	4020	3638
35	E Bldg 6165	7380	3064
36	N Bldg 5108	10530	9766

Table 4. (Cont'd).

No.	Location	Soil Resistivity With 5 Ft Pin Spacing (ohm-cm)	Soil Resistivity With 10 Ft Pin Spacing (ohm-cm)
37	N Bldg 4225	4020	2681
38	E Bldg 4370	4500	4596
39	S Bldg 4210	2780	4022
40	N Bldg 4057	8910	11682
41	N Bldg 4015	9580	14171
42	E Bldg 1934	2390	1724
43	N Bldg 1240	191510	130220
44	NW Bldg 1226	9290	28725
45	N Bldg 1366	4980	2681
46	N Bldg 3064	3450	2681
47	W Bldg 3088	3160	1915
48	NE Bldg 3100	3060	4022
49	N Bldg 3222	4790	1915
50	E Bldg 3300	5650	3638
51	S Ricketts Pt Rd	9580	14171
52	E Bldg 3312	5750	3638
53	W Bldg 2160	9190	13214
54	N Bldg 3563	28730	26810
55	NE Bldg 3580	22020	19150
56	SE Bush River & 22nd St	2300	1475
57	S Bldg 2182	7240	9192
58	NW Bldg 2204	13410	13788
59	NW Bldg 2314	3730	4213
60	NW Cadwalder & 25th St	6610	7660
61	S Bldg 2620	3830	5554
62	SE Bldg 3863	6030	3830
63	SE Bldg 2380	1440	2106
64	S Bldg 6202	37342	36385
65	NW Bldg 6210	8139	7277
66	NW Cedar Dr S & Cedar Dr E	9575	5745
67	S Cedar Dr E	18192	17618
68	NE Bldg 6542	40215	40215
69	NW Bldg 6528	47875	78515
70	SE Bldg 6560	114900	151285
71	E Bldg 6558	22980	21065

Table 5. Results from laboratory testing of soil.

Parameter	Bldg E1570: 2 ft above pipe	Bldg E3081 At pipeline depth	Line to Bldg E3835 Near Bldg E3724	Bldg E4445 Near manhole	Bldg E5126 Near first manhole SE of plant	Bldg E5360 Near manhole
pH	7.0	6.7	7.8	7.5	7.3	6.6
Paste pH	8.1	6.7	7.8	8.0	8.1	7.4
Resistivity (Ω-cm)	9932	12650	35600	43100	>44000	>44000
Sulfate (mg/kg)	118	586	67	88	<10	50
Sulfide (mg/kg)	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Chloride (mg/kg)	89	112	35	31	34	35
Moisture (%)	17.1	16.7	16.1	14.5	10.7	11.8
Total Acidity (mg/kg)	55	84	58	42	42	62

Soil resistivities in the areas surveyed at EA indicate that the soil should range from mildly to moderately corrosive in most areas. The laboratory tests indicated that the soil is only slightly corrosive at some locations. It is important to note that the Wenner four-pin technique, used to measure resistivities in the field, gives an average resistivity to a depth equal to the spacing of the pins, whereas laboratory testing gives the resistivity at the exact depth and location tested.

The most significant implication of the resistivity test results is that the soil resistivity in most areas surveyed was under 30,000 ohm-cm. As stated earlier, Army guidance requires that underground heat distribution and chilledwater piping in ferrous metallic conduit in soils with resistivity of 30,000 ohm-cm or lower is to be cathodically protected. Therefore, cathodic protection should be added to existing lines contained in ferrous metallic conduit. Any new lines with metallic casings that are direct-buried underground should be coated and cathodically protected. The soil is particularly corrosive to coated metallic structures where corrosion activity is accelerated at flaws in the coating. As discussed earlier, corrosion penetration of the casing allows for water infiltration and wets the insulation, leading to excessive heat losses and accelerated failure of the piping.

Soil pH

pH is a measure of an environment's hydrogen-ion activity. By definition,

$$pH = -\log[a(H+)] \qquad \text{[Eq 2]}$$

where a (H+) is the hydrogen-ion activity (concentration, for dilute solutions, in gram-ions/liter). Neutral environments have a pH of 7, alkaline environments have a pH greater than 7, and acids have a pH lower than 7. In general, the corrosion rate increases as the pH decreases below a pH of 7. The relatively neutral soil pHs measured at EA should not have a significant impact on the corrosion rate of buried steel.

Soluble Salts

The effect of soluble salts such as sodium chloride (NaCl) generally tend to increase the corrosion rate by decreasing the resistivity of the soil (i.e., increasing the conductivity of the soil). The presence of salts such as calcium sulfate ($CaSO_4$) can lead to accelerated corrosion of steel by the production of sulfate-reducing bacteria. The soils tested at EA had relatively high concentrations of chlorides and sulfates.

Sulfides

If sulfides are found in the soil, the presence of sulfate-reducing bacteria is likely. Sulfate-reducing bacteria can result in accelerated corrosion. Sulfides were not found in any of the soil samples tested at EA, so the data do not indicate the presence of sulfate-reducing bacteria.

Soil Moisture

In addition to the mineral content, moisture greatly affects a soil's resistivity. Resistivity decreases with an increase in moisture content up to a point near saturation. Seasonal differences in soil moisture can have a significant impact on the soil resistivity. In earlier USACERL research on the predictive modeling of the corrosion process for steel buried in soil, it was found that the moisture content of the soil does not significantly increase the corrosion rate unless it is above about 28 percent. The moisture content of the soils tested at EA was well below this threshold value at all locations.

Pipe-to-Soil Potential Survey

A pipe-to-soil potential survey was conducted at various locations throughout the E3000, E4000, and E5000 areas. Potentials were measured versus a copper-copper sulfate ($Cu/CuSO_4$) reference cell using a Fluke high-resistance multimeter. Potentials were evaluated to determine (1) existence and functionality of cathodic protection, (2) existence of electrical isolation from dissimilar metals such as copper, and

(3) existence of interference. APG personnel were not aware of cathodic protection on any of the buried lines owned and maintained by APG. Personnel stated that the steam and condensate lines owned and maintained by the waste-to-energy plant is cathodically protected with sacrificial anodes. Results of the pipe-to-soil potential survey are shown in Table 6.

The presence of cathodic protection on the waste-to-energy line was verified at the one tested location. It was also found that the new line to Bldg E3835 (pipe section 37A-3835) is cathodically protected. Several cathodic protection test stations were found along the line. The potentials measured indicate that protection is being supplied by magnesium anodes. APG personnel reported that annual pipe-to-soil potential surveys are not conducted. None of the other lines tested were cathodically protected. The values of the pipe-to-soil potentials of the unprotected lines fell within normal ranges

Table 6. Results from pipe-to-soil potential survey.

Location	Pipe-to-Soil Potential,V*
Steam line to Bldg 3081, at ground entry point	-0.590
Condensate line to Bldg 3081, at ground entry point	-0.536
Steam line at manhole between E5100 and 5126, near E5100	-0.440
4 in. steam line near Bldg 5360	-0.496
10 in. steam line near Bldg 5360, east of valve	-0.525
10 in. steam line near Bldg 5360, north of valve	-0.523
Bldg 5360, line on west side of valve	-0.523
8 in. aboveground steam line at Bldg 5604 (Alley Rd. & 34th)	-0.463
Near Bldg 3724- CP test station near manhole	-0.97
Near Bldg 3724- CP test station at manhole + 100 ft south	-1.06
Near Bldg 3724- CP test station at manhole + 200 ft south	-1.11
Near Bldg 3724- CP test station at manhole + 300 ft south	-1.06
Steam line in front of Bldg 1570	-0.513
Condensate line in front of Bldg 1570	-0.514
Waste-to-energy steam line near Bldg 5141	-1.04
Waste-to-energy condensate line near Bldg 5141	-0.996
Bldg 4445 near manhole-- condensate line running south	-0.52
Bldg 4445 near manhole-- steam line running south	-0.52
Bldg 4445 near manhole-- condensate line running back to plant	-0.526
Bldg 4445 near manhole-- steam line from plant	-0.525

for steel buried in soil. Neither electrical contact with dissimilar metals nor interference were detected at any of the testing locations.

In addition, data from the 1989 cathodic protection survey conducted by the U.S. Army Engineering and Housing Support Center—now the Center for Public Works—were reviewed (Spoerner 1989). Results of the survey indicated that none of the steam distribution lines owned by APG in the Edgewood area was cathodically protected. (Note: This is before the cathodically protected line to Bldg E3835 was installed.) The survey found that 97 percent of the locations tested on the waste-to-energy plant line met the criteria for cathodic protection.

Tests of Products Conveyed by the System

On 10 February 1993, two personnel from the U.S. Army Center for Public Works (USACPW) collected boiler, condensate, and makeup water samples for chemical analysis at boiler plants E5126, E3312, and E4160. Information on the chemical treatment applied at each plant was obtained from the boiler operators. The boilers in Bldgs E5126 and E3312 only supplement the steam supply from the waste-to-energy plant.

Boiler Plant E5126

This plant has six boilers. At the time of the survey, most of the load was being carried by boilers no. 5 and no. 6. Boiler no. 5 is a 1941 Union Iron Works 478 hp boiler, with a maximum capacity of 200 psi. It was operating at 130 psi. Boiler no. 6 is a 1985 Cleaver Brooks 600 hp watertube boiler with a maximum capacity of 260 psi. It was operating at 128 psi. The other boilers are smaller and were in wet layup at the time of the survey. All of the boilers have blowdown controllers on the continuous blowdown line. All makeup water is softened. The deaerator was operating at 230 °F and 7 psi. There is no condensate return to this plant; all returned condensate goes to the waste-to-energy plant. Treatment chemicals are supplied by Calgon Chemical. CB421™ is a combination of a dispersant and antifoam. CB260™ is sodium sulfite. Defend 327™ is a neutralizing amine which is used as a condensate corrosion inhibitor. Material Safety Data Sheets (MSDS) for the boiler treatment chemicals are reproduced in Appendix F. Chemicals are added to the boiler by feedpumps. Sample coolers were present on the boilers and the condensate sampling line for the waste-to-energy plant, but there was no sample cooler for the condensate from the APG boilers.

Boiler Plant E3312

There are five boilers in this plant. All were in layup at the time of this survey. The most recently fired boiler was boiler no. 4. The boilers are Cleaver Brooks firetube package boilers; the oldest was installed in 1975. There is a duplex softening system. The deaerator was not in operation at the time of the survey. Chemicals used here are Calgon CB421™, CB260™, CB150™, CB409™, and Magnamine 327™. CB421™ and CB260™ are described above. CB150™ is a combination of sodium hexametaphosphate and polyacrylate. CB409™ is a solution of caustic soda. Magnamine 327™ is a combination of morpholine, DEAE*, and sodium erythorbate.

Boiler Plant 4160

This plant has two boilers (boiler no. 1 and boiler no. 3). A new boiler no. 2 is to be installed in the future. The existing boilers are 1975 Cleaver Brooks firetube package boilers with a maximum operating pressure of 150 psi. Boiler no. 1 was operating at 22 psi and boiler no. 3 was operating at 25 psi. Steam from this plant goes to the 4000 area and does not mix with the waste-to-energy plant steam. Water is softened. The deaerator was operating at 235 °F and 9 psi. There is one chemical feed pump for each boiler. Chemicals used in this plant are the same as for Bldg E3312.

Results and Discussion

Results of the laboratory tests are given in Tables 7-9.

There were sample coolers on all of the boilers sampled, as well as a sample cooler for the waste-to-energy condensate line. This is a good feature of the systems.

The use of blowdown controllers on the boilers in E5126 is also very good. The load is so variable based on the output of the waste-to-energy plant that it is difficult to consistently maintain good chemistry without the controllers.

However, control of the water chemistry in all boilers requires improvement. In many cases, the values of the parameters tested were not within the Army-recommended ranges (Technical Manual [TM] 5-650).

Condensate samples collected at E5126 indicated the possibility of carryover from both the APG boilers and the waste-to-energy plant. The term *carryover* means that small droplets of the boiler water become entrained in the steam and are carried into the

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* DEAE: diethylaminoethanol.

Table 7. Boiler water chemical analysis results.

Bldg No.	E5126	E5126	E5126	E3312	E4160	E4160	E4225	Army Range*
Boiler No.	4	5	6	4	1	3	3	
Boiler Status	Wet Layup	On	On	On	On	On	On	
Total Dissolved Solids (mg/l)	2100	2000	2200	1950	650	850	1850	
Conductivity (μS/cm)	2610	2880	3160	2780	940	1210	2630	3000 - 3500
pH	12.8	12.3	12.5	12.5	11.4	11.7	12.5	
Sulfite (Na_2SO_3)	56	8	5	8	<2	<2	<2	20 - 40
Total Hardness ($CaCO_3$)	<2	<2	<2	<2	<2	<2	<2	
P Alkalinity ($CaCO_3$)	700	460	510	600	510	120	410	
Causticity, Hydroxide (OH^-)	130	850	940	1080	130	210	270	20 - 200
Orthophospate, Filtered (PO_4)	<1	16.8	18	36	<1	3	10	30 - 60
Tannin Color	1	<1	<1	<1	<1	<1	<1	

* *Army Range* refers to the Army-recommended range of values for this parameter as given in TM 5-650. These ranges are for boilers that are operating and do not include boilers that are in wet layup.

Table 8. Condensate chemical analysis results.

Building No.	E5126 W/E line	E5126	E4160	E4225	Army Range*
Color	Clear	Clear	Clear	Brown	
Total Dissolved Solids (mg/l)	200	110	11	64	
Conductivity (μS/cm)	287	222	15	92	< 35
pH	9.8	9	7.7	7.9	7.5 - 8.5
Total Hardness ($CaCO_3$)	<2	<2	<2	<2	<2
M Alkalinity ($CaC0_3$)	2	3	<1	2	
Total Suspended Solids	None	None	None	None	
Carbon Dioxide (mg/l)	----------	<1	14	21	
Total Iron (mg/l)	0.015	5.823	0.015	42.02	

* *Army Range* refers to the Army-recommended range of values for this parameter as given in TM 5-650. These ranges are for boilers that are operating and do not include boilers that are in wet layup.

Table 9. Boiler feedwater chemical analysis results.

Building No.	E5126	E4160	E4225
Total Dissolved Solids (mg/l)	110		110
Conductivity (µS/cm)	153		151
pH	8		8
Total Hardness ($CaCO_3$)	<2		<2
M Alkalinity ($CaCO_3$)	31		30

distribution system. Condensate conductivity over 35 µmho is considered a sign of excess carryover. The condensate sampled from the waste-to-energy line at E5126 had a conductivity of 287 µmho and the condensate sample from the APG condensate line at E5126 had a conductivity of 222 µmho. Operators need to check for carryover in condensate samples by performing a quick conductivity check. The chemical levels measured in the boilers themselves were not high enough to be causing carryover, but there could be some contaminant causing foaming in the boiler, or there could be a mechanical problem causing carryover.

There were high levels of iron in the condensate from Bldg E5126 (5.823 mg/l) and in the condensate from Bldg E4225 (42.02 mg/l), indicating that there is corrosion somewhere in the system. Corrosion testers are being installed in the condensate system to monitor corrosion rates. The testers consist of 2 in. diameter galvanized steel pipe nipples inside of which are enclosed six specially machined and preweighed "test ring" coupons (specimens). Testers will be installed for 90 days and removed. Corrosion rates will be determined by a weight-loss measurement technique. These corrosion testers are to be installed in the following locations:

1. Boiler plant E3312, near condensate pump to waste energy plant (on line where condensate is returned from system)
2. Boiler plant E4160, on main condensate return line (2 in. line) between the two boilers
3. Boiler plant E5126, near condensate pump to waste energy plant.

New testers should be used each year.

The total dissolved solids (TDS) levels in all of these boilers were lower than optimum for best energy efficiency, water consumption, and chemical consumption. The TDS levels ranged from 650 to 2,200 ppm. The optimum level is usually 3,000 to 3,500 ppm, if this can be achieved without the silica level exceeding 200 ppm in the boiler. This may be the case at EA. TDS levels are controlled by blowdown. The chemical supplier should be able to determine whether these boilers can reach optimum TDS levels. (Note that the lower the TDS levels in a boiler, the higher is the chemical usage

rate. Unnecessarily low TDS levels are often favored by sales representatives to increase chemical sales.)

Chemical levels in some of these boilers were not within control limits. Results showed that sulfite levels were very low in all of the on-line boilers tested. The Army-recommended sulfite level for on-line boilers is 20 –40 ppm; the boilers tested here had sulfite levels ranging from less than 2 ppm to 8 ppm.

Phosphate levels were very low in all of the boilers tested except for one. The Army-recommended range for phosphate is 30 – 60 ppm. Boiler no. 4 at Bldg E3312 was the only boiler within this range with a phosphate level of 36 ppm. The other boilers tested here had phosphate levels ranging from less than 1 ppm to 18 ppm.

Causticity was excessively high in three of the boilers tested and slightly high in two others. The Army-recommended range for causticity is 20 – 200 ppm. Boilers no. 5 and no. 6 at Bldg E5126 and boiler no. 4 at Bldg E3312 had causticities in excess of 800 ppm. Levels were slightly high in boiler no. 3 at Bldg E4160 and in boiler no. 3 at Bldg E4225.

One of the boilers, no. 4 in Bldg 5126, was in wet layup at the time of the survey. The sulfite and causticity levels were low for layup conditions. The recommended minimum sulfite level for wet layup is 200 ppm; the level in this boiler was 56 ppm. The recommended minimum causticity level for wet layup is 500 ppm; the level in this boiler was 130 ppm.

As a potential remedy to the problem of controlling chemical levels, a proportional chemical feed system should be strongly considered for these boilers. The chemical feed pumps can be controlled by pulsing makeup water meters. This system would greatly facilitate maintaining chemical control. A typical proportional feed system costs about $500. The Calgon sales representative should be able to sell and install them. The installation of proportional feed systems is in the best interest of the chemical company because these systems make the treatment chemical look better for controlling scale and corrosion.

4 Conclusions and Recommendations

Conclusions

1. The overall heat distribution system at APG/ EA was found to be in fair to poor condition according to the criteria set forth in Chapter 3.
2. The most common defects found on the underground system were (1) the presence (or evidence) of standing water in the manholes and (2) the lack of insulation on much of the piping in the manholes. The major factor contributing to the problem of standing water in the manholes is the complete absence of sump pumps in the system.
3. The most common defect found on the aboveground system was missing and damaged pipe insulation: an estimated 2,000 feet of aboveground piping was found to be without insulation.
4. Soil test results in the areas surveyed at EA indicate that the soil probably ranges from mildly to moderately corrosive in most areas.
5. The cathodic protection survey revealed the presence of cathodic protection on only one line.
6. Testing of the boiler water and condensate revealed problems with chemical control in the boilers at APG/EA. The values of several key chemical parameters were not within the Army-recommended ranges as set forth in TM 5-650. In addition, a high iron content was observed in the condensate from two different locations. This indicates that CO_2 or O_2 corrosion is occurring in the system.

Recommendations

The recommendations that follow are organized according to the three principles discussed in Chapter 2 for maximizing the performance of a heat distribution system:

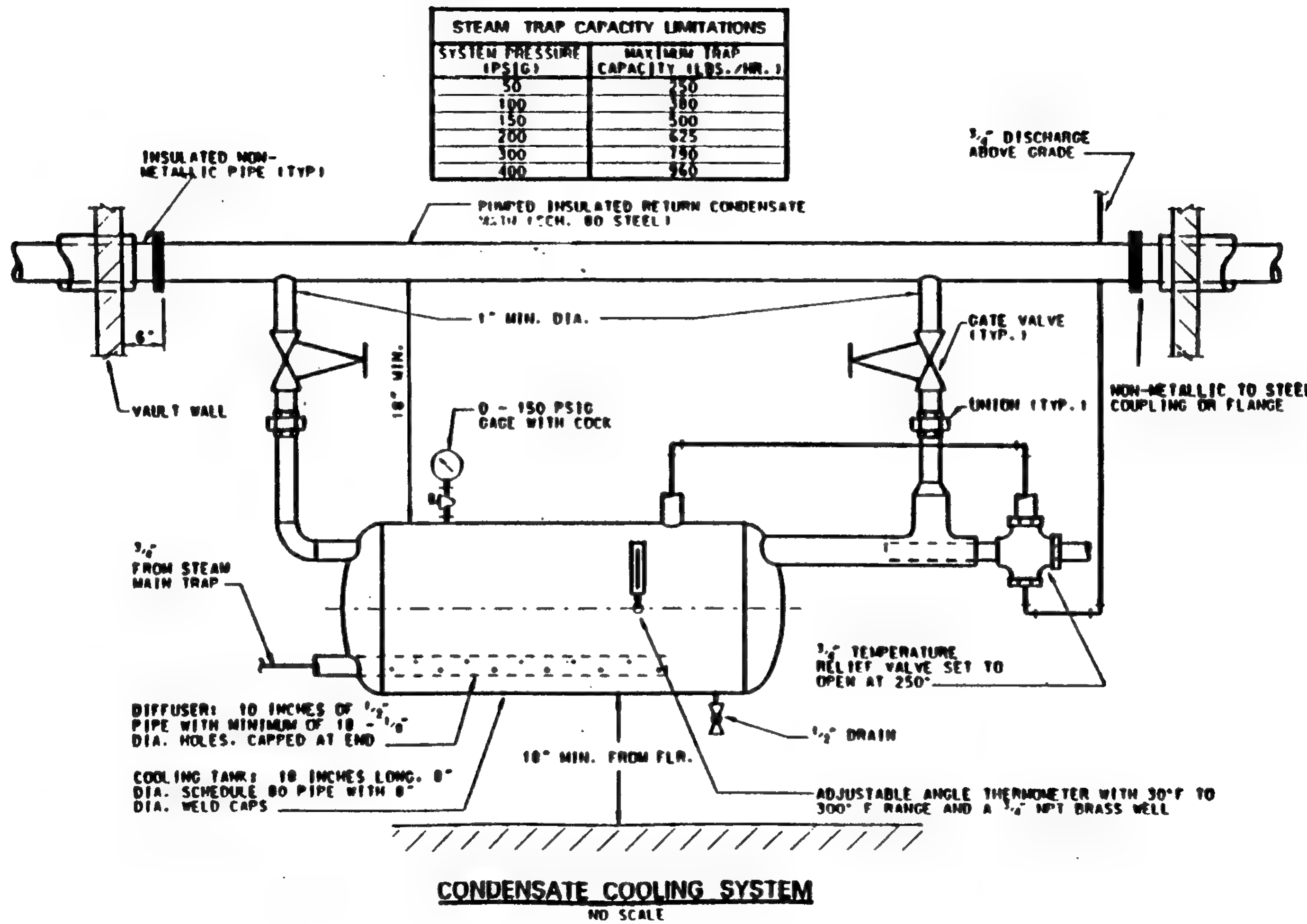
1. replacement or rehabilitation of severely deteriorated, unsafe, or improperly functioning components
2. execution of a good ongoing maintenance program that is tailored to the specific corrosion and deterioration problems at the installation
3. ensuring that any system replacements or new systems are specified and installed in accordance with current standards and guidance.

Please note that the recommendations under "Replacement or Rehabilitation" (immediately below) should be followed in conjunction with the condition ratings and inspection comments given in Appendix C. Any costs specified in the recommendations (except for the sump pump cost) are based on the findings of Uzarski (July 1991) and Demetroulis (May 1990), but adjusted to 1994 dollars assuming a 4 percent annual inflation rate.

Recommendations for Repair or Replacement of Unsafe or Malfunctioning Components

Short-Term Replacement/Rehabilitation Recommendations:

1. On the aboveground lines, bare sections of piping and sections with damaged insulation and covering should be reinsulated and covered with an aluminum casing. Because many of the older lines at EA are covered with asbestos insulation, full compliance with all worker safety and environmental regulations will add cost to this work.
2. On underground lines, bare piping in manholes should be insulated and covered. Insulation at valves should be of the removable, reusable blanket type. Insulating and covering bare piping in manholes costs about $5.85 per linear foot.
3. Before or during the reinsulation of pipes, it is recommended that good quality electric sump pumps or drainage piping to the storm sewer (with a back-check valve) be installed. Installation of power and sump pumps at APG costs approximately $7,000 to $10,000 per manhole. Specific requirements are given in CEGS 02695. (This guide specification requires the installation of a dedicated electric line to the pump and the posting of a sign to warn personnel that power service is not to be interrupted.)
4. Steam condensate leaks should be repaired as quickly as possible to prevent excessive heat losses. In lines where multiple failures have occurred, consideration should be given to replacing the line.
5. To address the failures in the FRP condensate return line system in the 5000 area, which are probably caused by the release of live steam into the condensate system through failed steam traps (Chapter 3), it is recommended that a condensate cooling system be installed at each steam trap. The approach described in Army TM 5-810-17, sec 8-2e is recommended (see Figure 26).
6. As a safety precaution, the damaged, corroded, and loose access ladders in manholes should be replaced with prefabricated, galvanized steel ladders rigidly attached to the manhole walls. A new ladder costs approximately $170 per manhole.



(Source: TM 5-810-17.)

Figure 26. Schematic of condensate cooling system.

7. All aboveground anchor assemblies should be checked to ensure anchor stability. Broken and badly corroded guy wires should be replaced and guy wire tensions should be equalized.
8. Pipe supports and guides should be repaired to ensure proper operation. Special consideration should be given to broken and corroded moment guides at expansion joints in manholes.
9. At many of the conduit wall penetrations on the underground system's manholes, the caulking is no longer effective at keeping water out of the manhole. Caulking should be replaced as required. Old manhole penetrations should be sealed with concrete and waterproofed. Replacement of caulking inside the manhole costs about $47 per penetration.
10. Excessively corroded manhole internals should be replaced. This includes valves, piping, vents, supports, traps, and conduit end plates. The average cost of replacement is $175 each.
11. Before any maintenance or demolition of the aboveground systems, additional testing should be performed to determine whether lead-based paint is present beyond the single location at which it was found. Initial tests for lead can be performed inexpensively with any commercially available test kit approved by an appropriate national standards organization. Additional information on the regulations that must be considered, as well as on testing for the presence of lead, is given in Appendix G.
12. Leaking flange gaskets and valve packing should be replaced. This costs approximately $120 per location.
13. Excess vegetation (including several trees) growing up between the aboveground lines in the 3000 area should be removed.
14. Many of the screens on the manhole tops are missing and should be replaced to prevent debris from collecting in the manholes. Screen replacement costs approximately $4.70/sq ft.

Long-Term Replacement/Rehabilitation Recommendations:

1. The 4 in. condensate return line in the 3000 area extending from the boiler plant to near Bldg 3725 (section ID 3312-37A) is in extremely poor condition and should be replaced.
2. It is recommended that an economic analysis should be conducted to determine potential savings and payback period for the installation of condensate return lines in locations where condensate is dumped. Because of its vulnerability to failure, FRP should not be used for the new lines.
3. To provide greater flexibility in the operation and maintenance of the heating system, it is recommended that the Edgewood Area DPW consider installing a modified loop or interconnecting lines between heat plants. This enhancement

would allow operation of only one plant during low-load periods, leaving the others available for inspection and maintenance without disrupting service. If properly sectionalized (with valves), this concept would also allow for system emergency repairs with minimal impact on heat service to individual buildings.

4. A review is recommended to determine the cost of locating and replacing individual failed traps. This review should compare the costs of location and replacement with those of a scheduled program of trap replacement (using high-quality components). Consideration should be given to using high-quality inverted bucket traps such as those described in Maga (November 1991), or thermostatic traps with a delta-loop feature, which have been the subject of favorable comments from maintenance personnel at Ft. Lewis, WA, and Grissom Air Force Base (AFB), IN (Charles Keller and Jim Thayer, DPW, Fort Lewis, WA, telephone conversation, 3 September 1993; James Williams, Grissom AFB, IN, 14 July 1993). Replacement of a failed steam trap costs approximately $88.00.

Recommendations for a More Effective Maintenance Program

The following recommendations address four general elements of an effective maintenance program:

- a thorough, well monitored boiler water chemical treatment program
- a regular, systematic inspection program
- periodic testing of cathodic protection systems
- complete and accurate recordkeeping.

Boiler Water Chemical Treatment Program:

1. It is strongly recommended that boiler water and condensate chemistry immediately move within and be maintained at the Army-recommended control ranges specified in TM 5-650, and as set forth in the "Army Range" column of Tables 7 and 8 (Chapter 3).
2. It is recommended that proportional chemical feed systems immediately be installed on operating boilers. As noted earlier, these systems cost about $500 per boiler.
3. Maintain TDS levels of at least 2000 ppm by decreasing blowdown when necessary. The optimum level is 3000 to 3500 ppm. Obtain Calgon's input on how to increase the TDS level.
4. Reduce carryover at boiler plant E5126 as much as feasible.
5. Install sample coolers at all condensate sampling points.

6. Collect condensate samples on a regular basis from different points in the system and have them analyzed to help determine the cause of corrosion in the condensate system.
7. Install corrosion testers at various locations in the main condensate return system to further identify and locate the cause of corrosion.
8. Participate in the Army's Boiler Water Quality Assurance Program. An information paper briefly describing this program is reproduced in Appendix H.
9. Consult with the U.S. Army Center for Public Works (USACPW) when necessary for assistance with questions on boiler water chemistry.
10. Personnel who are responsible for performing, specifying, or supervising the chemical treatment of boiler water should attend USACPW's Boiler Water Treatment Workshop. This workshop is sponsored by the Sanitary Chemical Division (CECPW-ES) and is held two or three times per year at Fort Belvoir, VA.

Systematic Inspection Program:

1. It is recommended that the procedures for inspecting underground heat distribution systems (Demetroulis, Hock, and Segan, March 1991) be implemented at EA, including annual manhole inspections. This type of inspection costs approximately $200 per manhole.
2. It is recommended that the aboveground system be inspected regularly, with deficiencies noted and repaired. USACERL has not yet published formal guidelines for conducting this kind of an inspection, but such guidelines are anticipated as a product of scheduled research and development. In lieu of formal guidelines, the following items will be covered during inspection of the aboveground system:
   - deterioration of casing
   - missing, wet, or otherwise damaged insulation
   - leaking pipes
   - leaking valves or flanges
   - steaming around system components
   - deterioration of supports, including rusting, bending, failed coating, failure of the pipe to rest on the support, or other deterioration which affects functionality and/ or safety
   - corroded or slack support wires
   - vegetation around lines.

3. It is recommended that DPW personnel investigate the possible benefits of commercially available computer programs that may enhance the installation's steam trap maintenance program. Steam traps should be inspected regularly and failed traps should be replaced as stated previously.

Periodic Testing of the Cathodic Protection System:

1. It is recommended that the sacrificial anode cathodic protection system on the line to Bldg E3835 be tested annually to ensure that the system continues to provide corrosion protection to the coated line and, thus, help to maximize the life of this relatively new line. A pipe-to-soil potential survey should be conducted along the entire length of the line, and the results should be evaluated against the National Association of Corrosion Engineers' criteria for cathodic protection (Standard Recommended Practice RP0169-92). Any problems indicated by the test results should be remedied promptly to ensure that the line does not fail prematurely due to soil-side corrosion. Information on cathodic protection testing is included in Appendix I.
2. It is recommended that APG/EA use the USACERL-developed Cathodic Protection Diagnostic program (Appendix I) to store and evaluate cathodic protection test data. This program can be used to store data on cathodic protection systems for all underground piping systems, underground storage tanks, and elevated water storage tanks.
3. Personnel who are responsible for performing, specifying, or supervising the testing of cathodic protection systems should attend the PROSPECT Corrosion Control Course or the Facilities Engineer Corrosion Course. Both courses are offered annually at USACERL.

Recordkeeping

1. It is recommended that centralized maintenance/repair/leak records be kept to document justification for major repair projects, replacements, or installation of cathodic protection, and to help to establish the locations of recurring problems.
2. It is recommended that the current efforts to computerize utility maps on the installation GIS incorporate the leak and repair records described above. It is also recommended that the GIS be used to record the inventory, condition assessment, and soil testing information in the test and appendices of these reports. Incorporating these data into the GIS will provide a reliable, uniform set of information and frame of reference for all DPW engineers and planners.

Recommended System Replacements

1. It is recommended that APT/EA discontinue the use of system piping systems and materials not approved by FAC (i.e., steel pipe covered with fiberglass insulation and Protexulate™. An FAC pre-engineered, pre-approved piping system should be used for all replacements and should be installed in accordance with the FAC approved brochure. Details are in CEGS 02695.

2. It is recommended that aboveground distribution systems be used wherever feasible, because of their ease of inspection and maintenance, as well as their low life-cycle cost. See CEGS 02697 (May 1991) for current Army guidance on aboveground heat distribution systems.
3. It is recommended that the slab-on-grade concrete trench system be used where aboveground systems are not permitted (e.g., housing, administrative areas). Current Army guidance on this system—a protective concrete trench in which insulated piping is mounted on sliding supports or rollers, with easily removable trench lids for leak location—is specified in TM 5-810-17.
4. In areas with extremely high water tables that could flood a concrete trench, a preapproved drainable-dryable conduit system is recommended. CEGS 02695 lists those companies who currently have FAC-accepted brochures.
5. It is recommended that raised-top, reinforced concrete manholes with solid aluminum plate covers be used in future construction and replacement. This type of manhole—the "Omaha design"—provides easy access and an excellent environment for inspection and repairs. The section from TM 5-810-17 that describes the Omaha design is reprinted in Appendix J.
6. It is recommended that fiberglass-reinforced plastic condensate return lines no longer be used because of the high potential for line failure when live steam enters the line due to a steam trap failure.

References

ASTM G57-78 (R84), *Standard Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method* (American Society for Testing and Materials, 1984).

Beard, James B., *Turfgrass: Science and Culture* (Prentice Hall, 1973).

Corps of Engineers Guide Specification (CEGS) 02695, *Underground Heat Distribution System and Condensate Return System* (Headquarters, U.S. Army Corps of Engineers [HQUSACE], May 1991).

CEGS 02697, *Aboveground Heat Distribution System* (HQUSACE, May 1991).

Demetroulis, N.M., V.F. Hock, and E.G. Segan, *Guidance for Manhole Rehabilitation in Army Underground Heat Distribution Systems*, Technical Report [TR] M-91/01/ADA233709 (U.S. Army Construction Engineering Research Laborabories [USACERL], March 1991).

Demetroulis, N.M., *Procedures for Inspection of Heat Distribution Systems at Fort Dix, NJ* (Contractor report prepared for USACERL, May 1990).

Engineer Technical Letter (ETL) 1110-3-440, *Cathodic Protection*, (HQDA, 20 August 1992).

Guglomo, R.C., V.L. Van Blaricum, C.D. Page, and A. Kumar, *MicroGPIPER Implementation Guide*, TR FM-92/04/ADA256755 (USACERL, July 1992).

Husock, B., *Evaluation of Cathodic Protection Criteria*, Engineering and Services Laboratory (ESL) TR-79-14 (Headquarters, Air Force Engineering and Services Center, April 1979).

Maga, S., *Steam Loss Test of Steam Traps*, unnumbered contractor report prepared for USACERL (Naval Civil Engineering Laboratory Report, November 1991).

Marsh, C., "Lessons Learned to Date From the Fort Jackson, SC, FEAP Heat Distribution Systems Demonstration Project," *Proceedings of the 1992 Electrical-Mechanical Conference* (July 1992).

McCammon, T.L., and M.J. Savoie, *Thermal Energy Supply Optimization for Edgewood Area, U.S. Army Aberdeen Proving Ground: Energy Supply Alternatives*, USACERL TR 95/01 (USACERL, May 1995).

McLeod, M.E., and M.P. Barthelmy, *Corrosion Survey Report, Aberdeen Proving Ground, Maryland*, Report No. ED-7707 (U.S. Army Facilities Engineering Support Agency, 19 December 1977).

Myers, J.R., E.G. Segan, C.P. Marsh, and V.F. Hock, *Causes and Control of Corrosion in Buried-Conduit Heat Distribution Systems*, TR-M-91/08/ADA238958 (USACERL, July 1991).

Spoerner, T. W., *Cathodic Protection Systems Evaluation: Aberdeen Proving Grounds and The Edgewood Arsenal, MD*, Report No. E-89052 (U.S. Army Engineering and Housing Support Center, May 1989).

Technical Manual (TM) 5-650, *Central Boiler Plants* (Headquarters, Department of the Army [HQDA], 1 August 1962).

TM 5-810-17, *Heating and Cooling Distribution Systems* (HQDA, 1994).

Standard Recommended Practice RP0169-92, *Control of External Corrosion on Underground or Submerged Metallic Piping Systems* (National Association of Corrosion Engineers, April 1992).

Uzarski, D.R., R.E. Rundus, D.M. Bailey, M.J. Binder et al., *Layaway Procedures for U. S. Army Facilities, Volume I: Decision Criteria and Economics*, TR M-91/23/ADA240054 (USACERL, July 1991).

Appendix A: Maps Showing Locations of Nodes, Manholes, and Pipe Sections

To facilitate identification of system elements, a naming scheme was developed for the key components of the heat distribution system. System nodes are designated either by building numbers, or, where a node does not correspond with a building, the nodes are given an alphanumeric designation such as "37A." Manholes also were numbered to facilitate their identification. In general, manhole identifications were assigned for each area beginning at the heating plant and proceeding around the loop. The manholes closest to the plant in each area (E3312, E4160, and E5126) were assigned the numbers 3000, 4000, and 5000, respectively. Identification numbers were assigned to subsequent manholes based on increments of 10.

APG personnel wished to be able to easily correlate this naming scheme with their existing 40-scale maps. For this reason, the maps have been reduced and included in this report. The maps show the specific locations of buildings, nodes, pipe sections, and manholes along with their assigned identifications. The 8.5 × 11 in. maps on the following pages are 65 percent reductions of the 40 scale maps of the utility distribution systems at Edgewood Area. The 40-scale maps were marked with node, manhole, and pipe section identification numbers. To facilitate inclusion of the maps in this report, each 40 scale map was divided into quadrants according to the following chart:

Sample 40-Scale Map

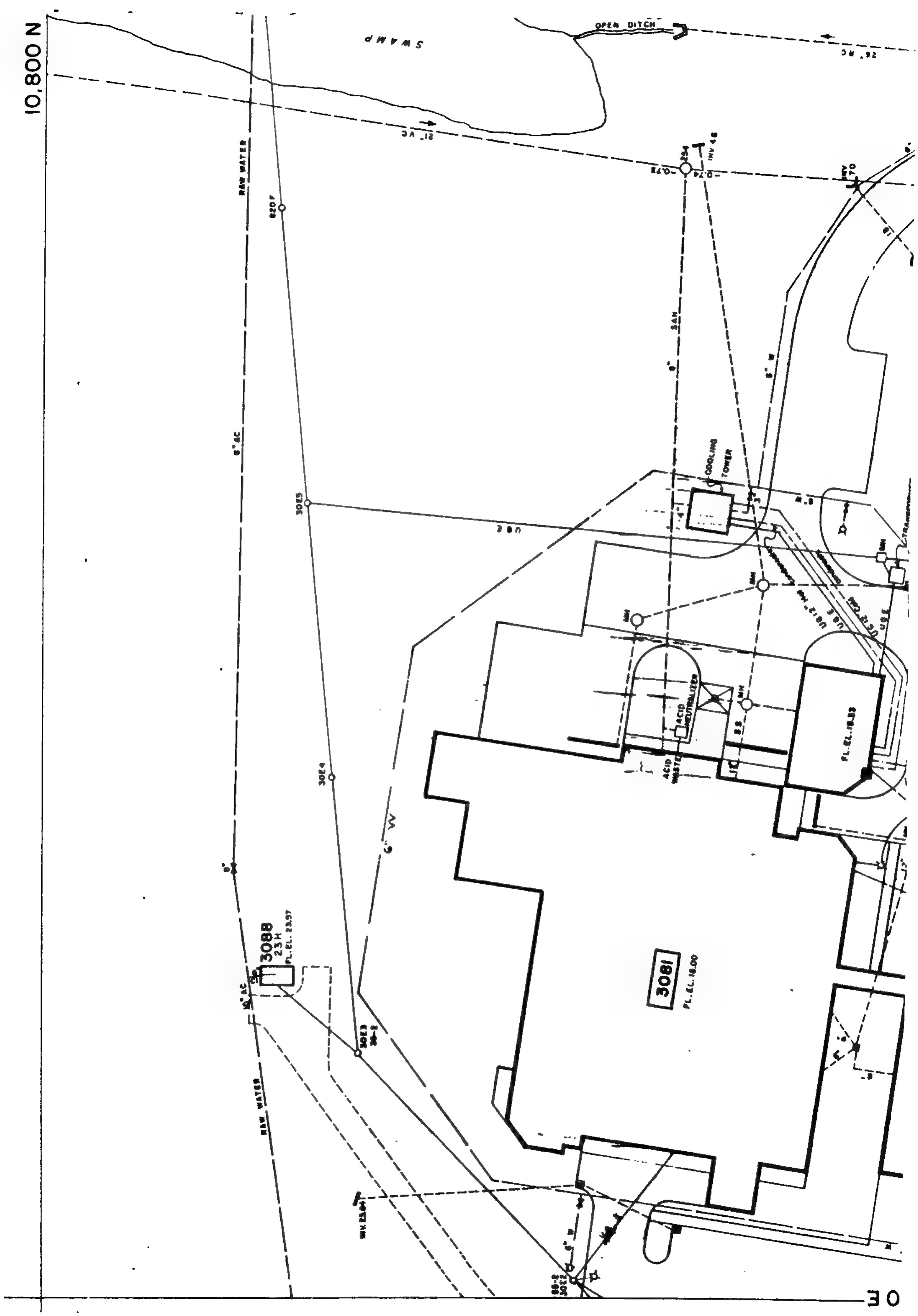
1	2
3	4

Each quadrant of the map was reduced by 65 percent to a size of 8.5 × 11 in. Each reduced quadrant map was identified by first giving the number of the 40-scale map sheet, followed by a hyphen, followed by the number of the map quadrant. For

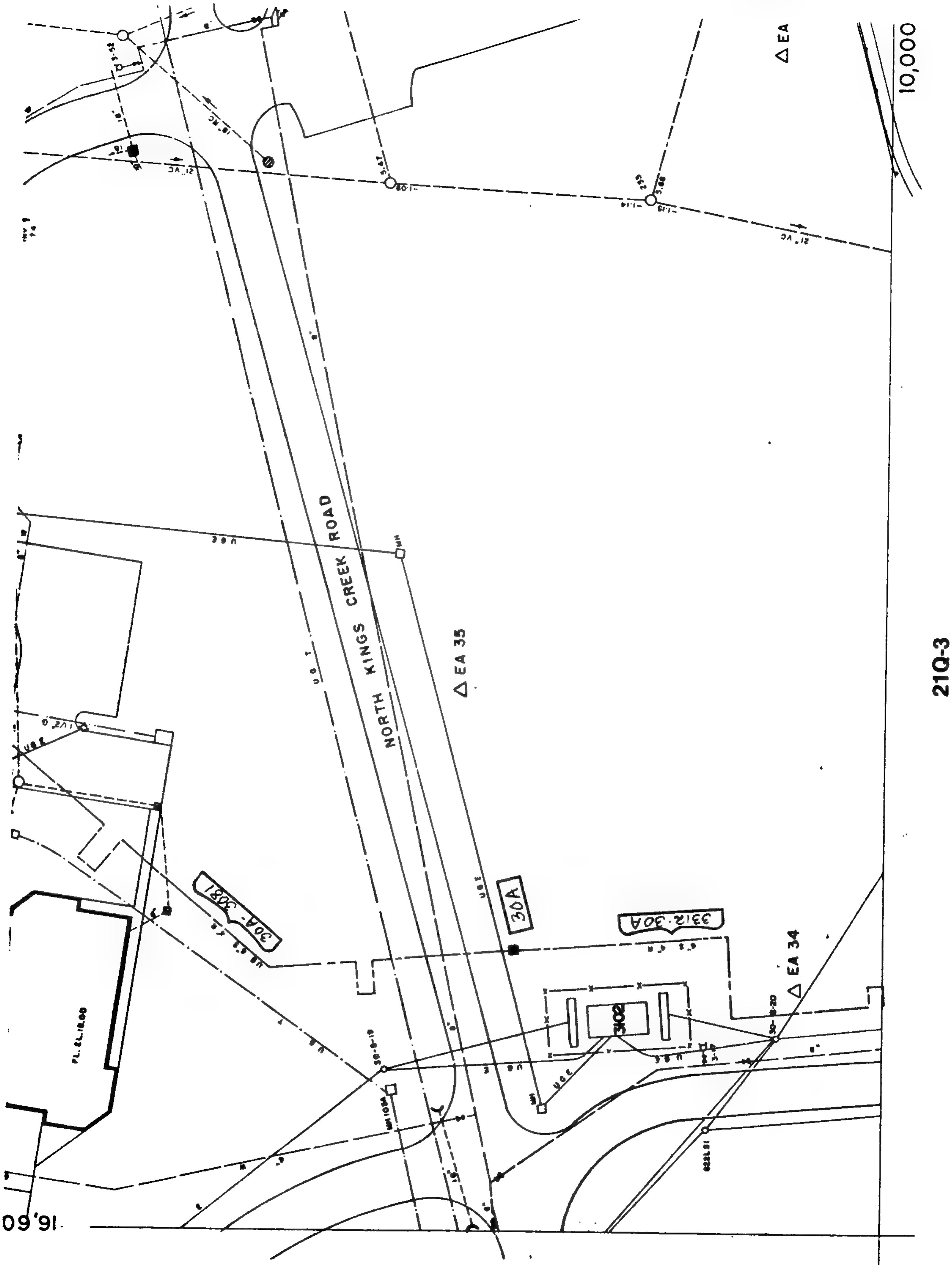
example, the sheet representing the lower right-hand quadrant of 40 scale map sheet number 23L would be identified as 23L-4. The layout chart below gives the exact layout of the map sheets for the 3000 area. The map sheets identified in the chart are reprinted after the chart, arranged in alphanumeric order. A layout chart for the 4000 area is then shown, followed by the 4000 area quadrant map sheets. Finally, a layout chart for the 5000 area is given, followed by the 5000 area quadrant map sheets.

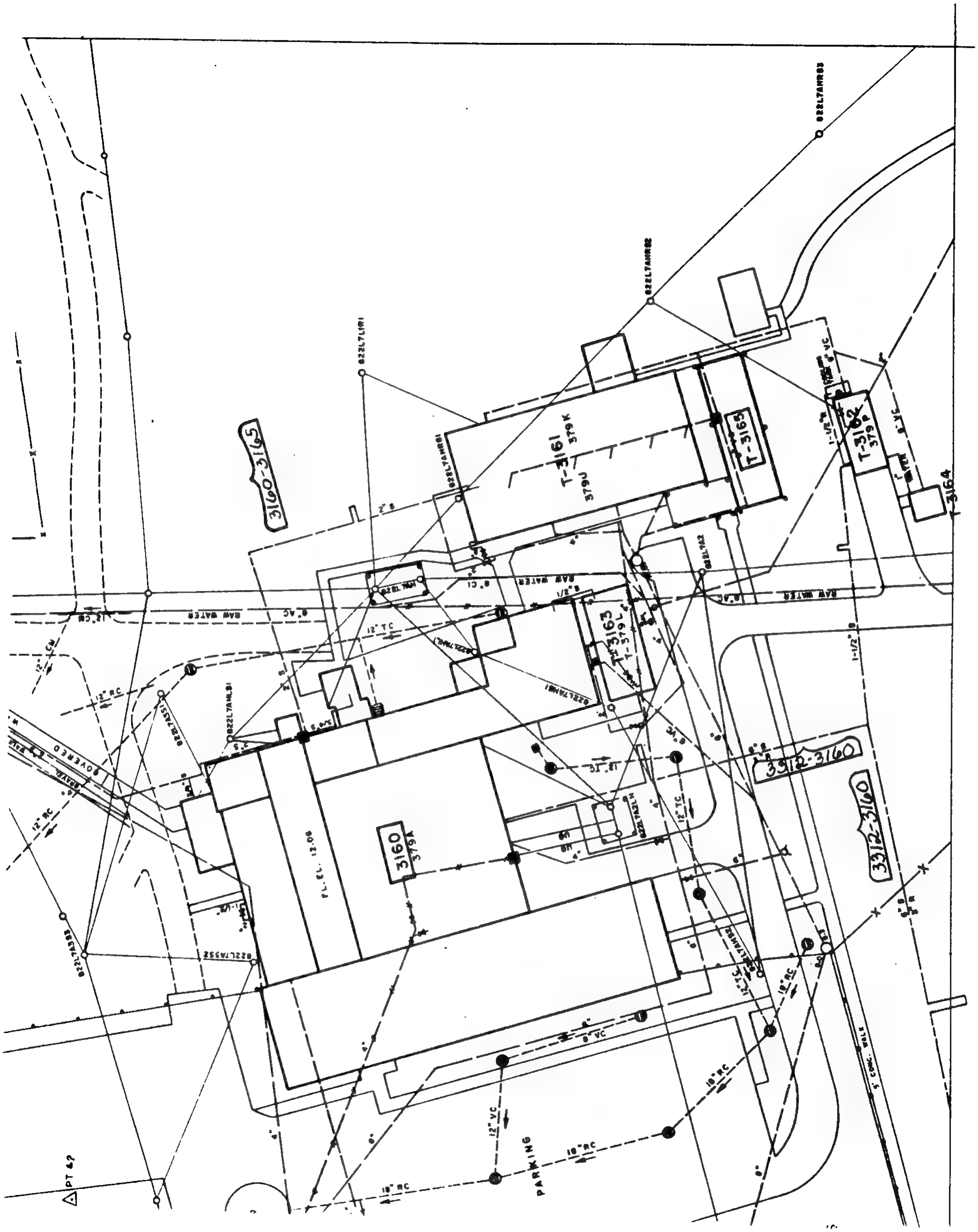
Layout Chart for 3000 Area Quadrant Map Sheets

	21Q-1				
	21Q-3	21Q-4			
22P-2	22Q-1				
22P-4					
23P-2					
23P-4					
24P-2	24Q-1				24S-1
24P-4	24Q-3	24Q-4	24R-3	24R-4	24S-3
25P-2	25Q-1	25Q-2	25R-1		25S-1
	25Q-3		25R-3		

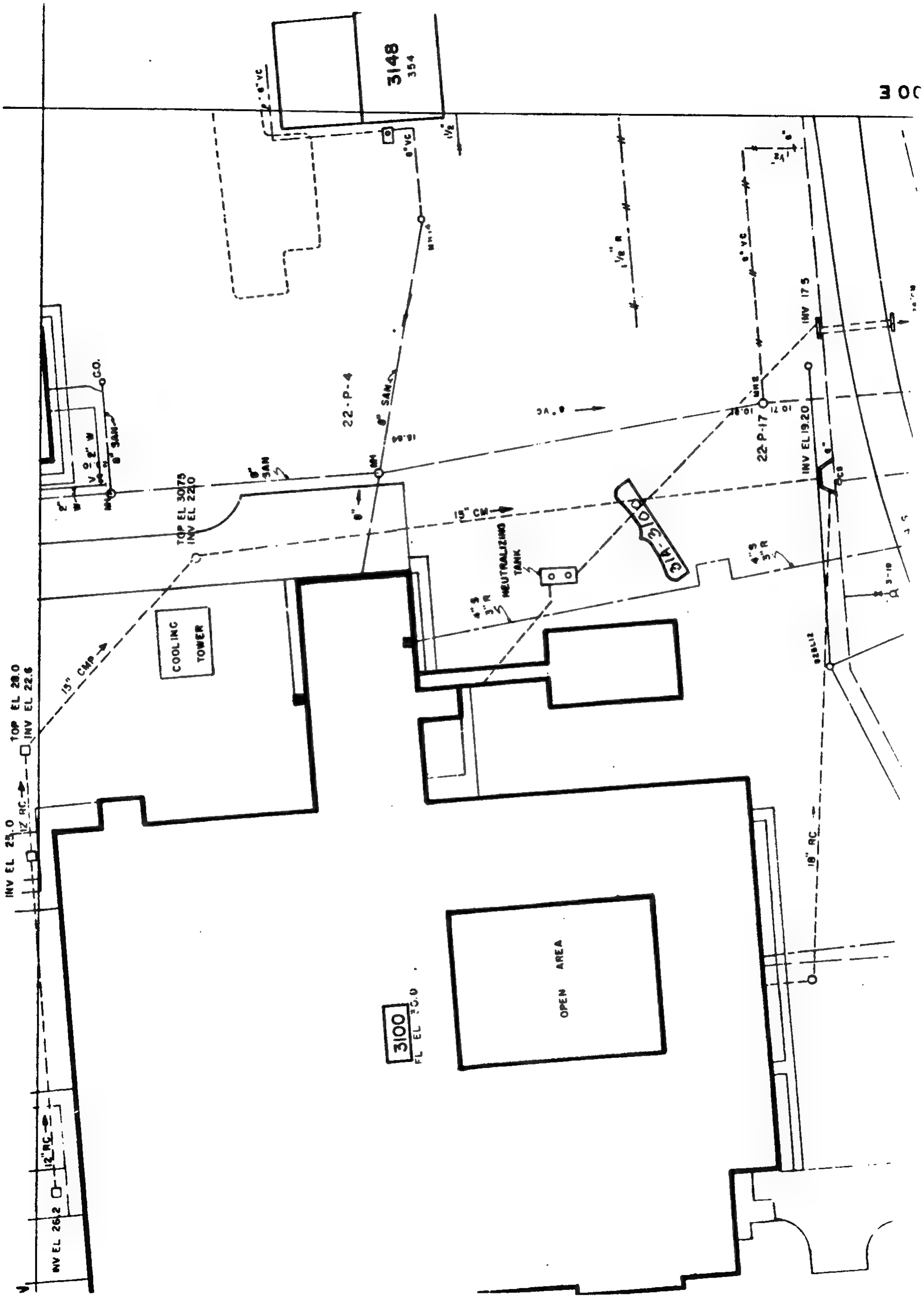

10,800 N
SWAMP
OPEN DITCH
RAW WATER
COOLING TOWER
ACID NEUTRALIZER
ACID WASTE
3081
PL. EL. 18.00
3088
PL. EL. 23.97
30E5
30E4
30E3
0 E

21Q-1

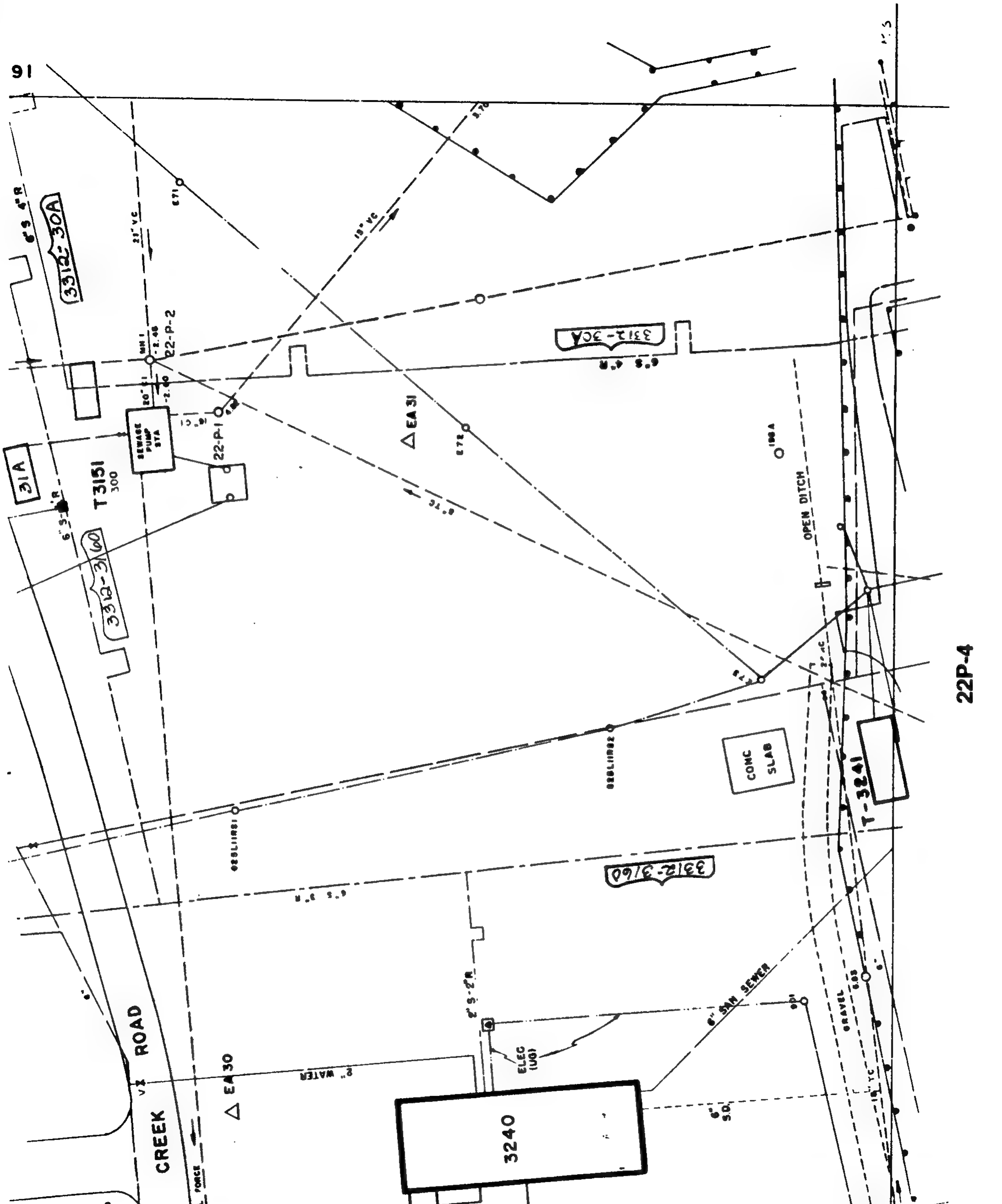

NORTH KINGS CREEK ROAD
Δ EA 35
Δ EA 34
Δ EA
10,000
30A
3312-30A
30A-3081
3102
21Q-3

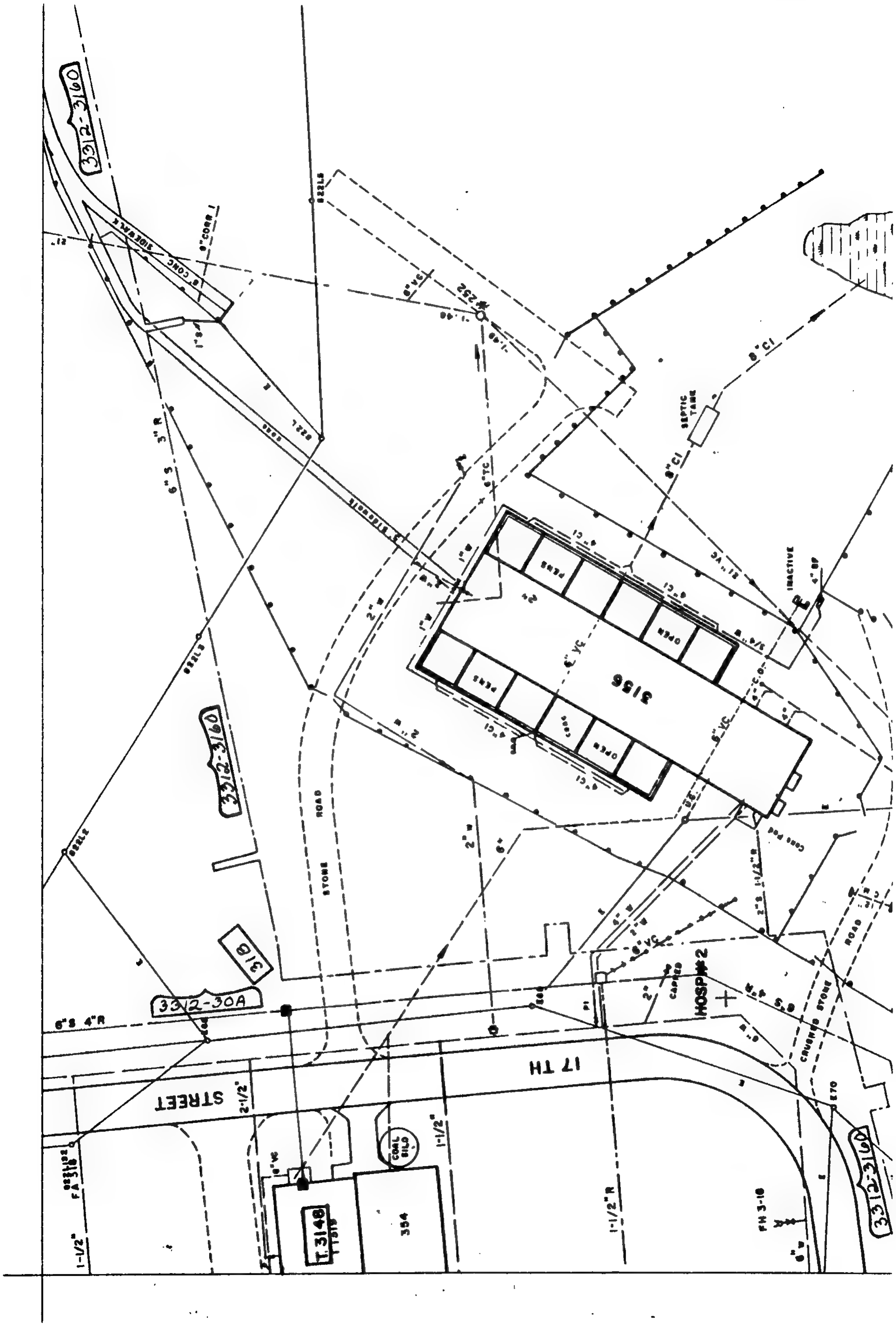

3160-3165
T-3161
379K
379U
T-3165
T-3162
379P
T-3164
T-3163
T-379L
3160
379A
3312-3160
PARKING
RAW WATER
PT 42

21Q-4

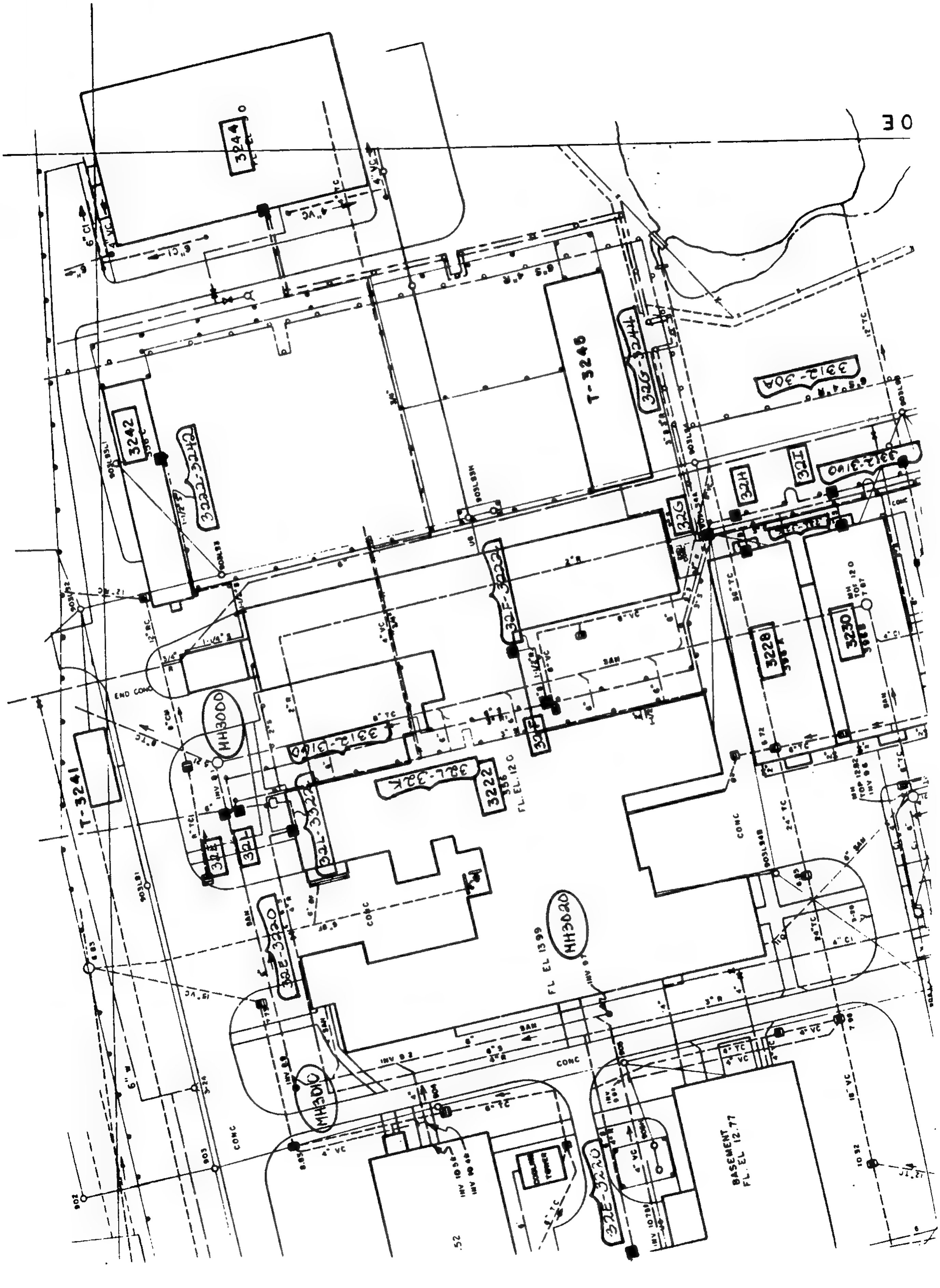

3148
354
COOLING TOWER
NEUTRALIZING TANK
22-P-4
22-P-17
3100
OPEN AREA
TOP EL 30.75
INV EL 22.0
TOP EL 28.0
INV EL 22.6
INV EL 25.0
INV EL 26.2
INV EL 19.20
INV 17.5
15" CMP
18" RC
12" RC
8" SAN
6" VC

22P-2

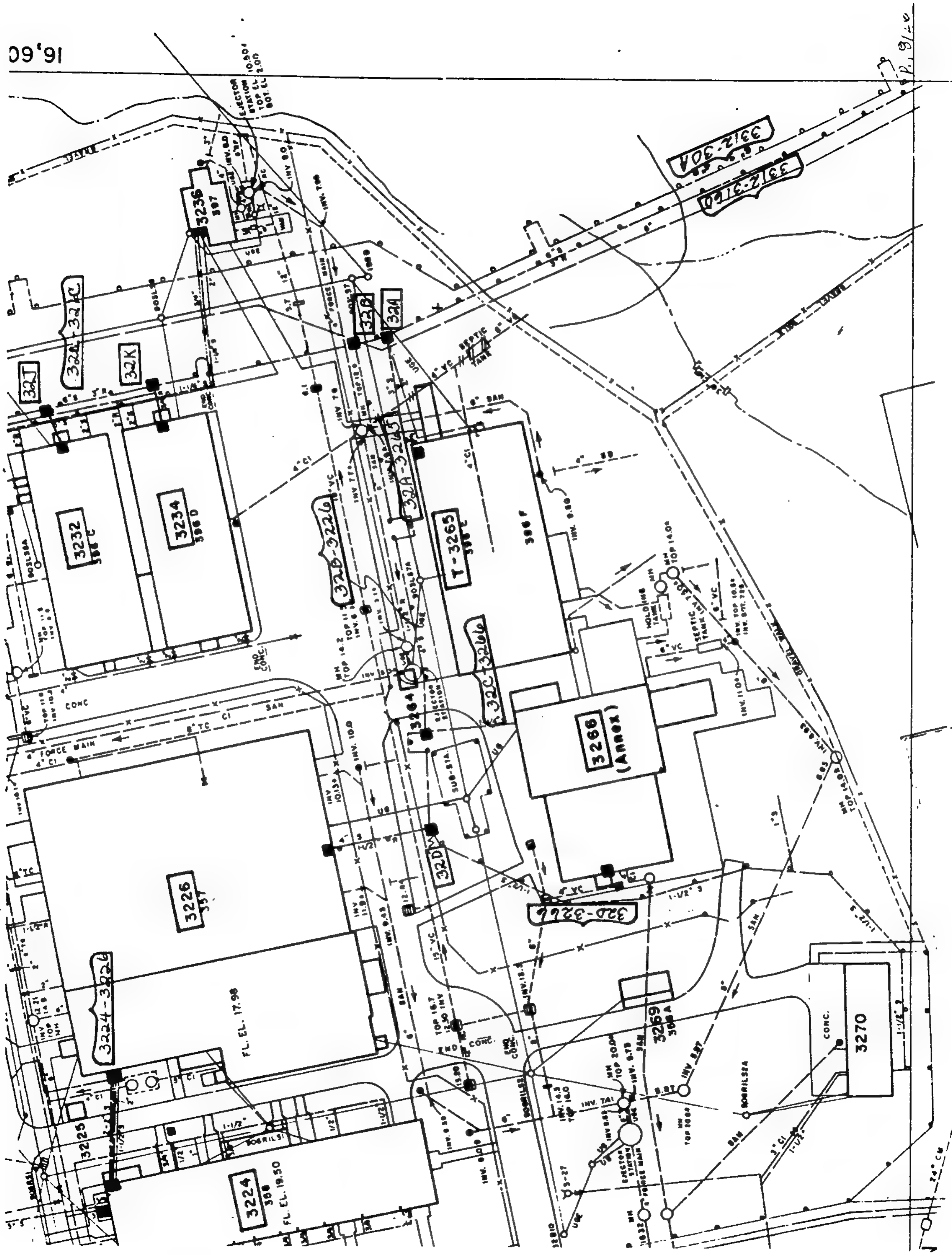

91
3312-30A
3312-3CA
3312-3160
31A
T3151
300
SEWAGE PUMP STA
22-P-1
22-P-2
EA 31
EA 30
OPEN DITCH
CONC SLAB
T-3241
3240
6" SAN SEWER
2" WATER
ELEC (UG)
GRAVEL
KINGS CREEK ROAD
22P-4


3156
17 TH
STREET
HOSP #2
SEPTIC TANK
COAL SILO
354
T.3148
3312-3160
3312-30A
318
STONE ROAD
CRUSHED STONE ROAD
INACTIVE
FH 3-18

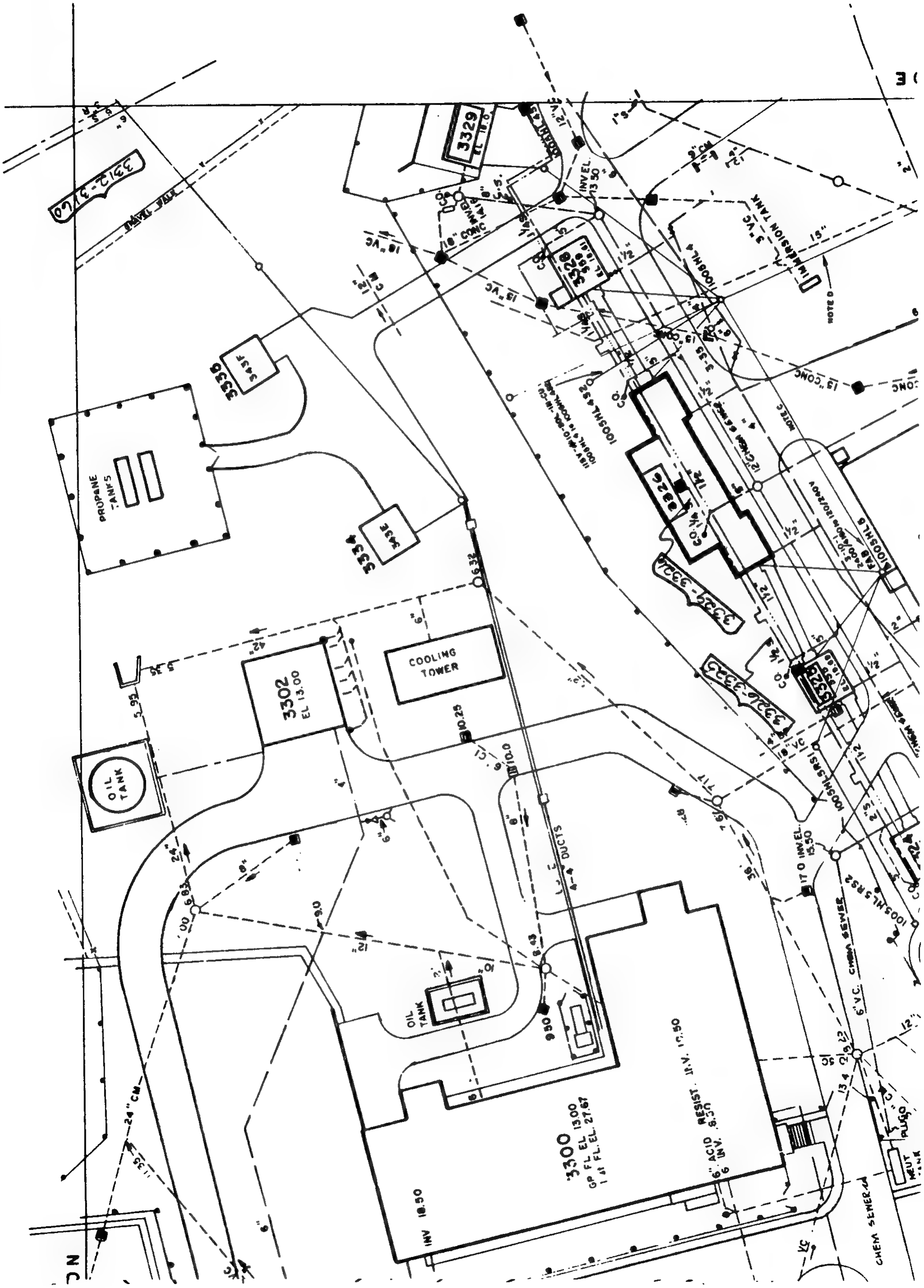
22Q-1



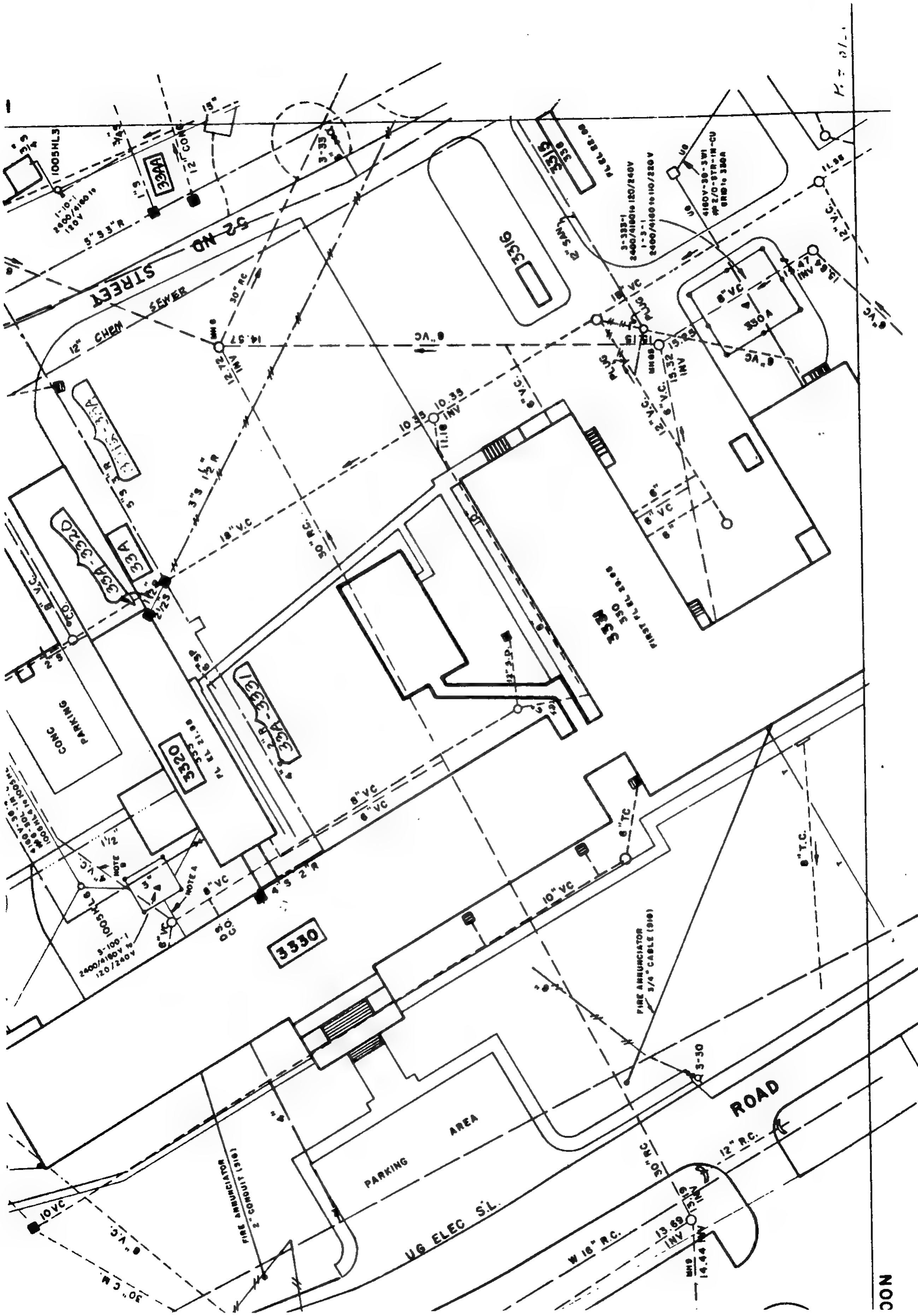
23P-2


16,60
3236
3232
3234
T-3265
3266 (Annex)
3226
3224
3225
3264
3269
3270
FORCE MAIN
SUB-STA.
FL. EL. 17.98
FL. EL. 19.50

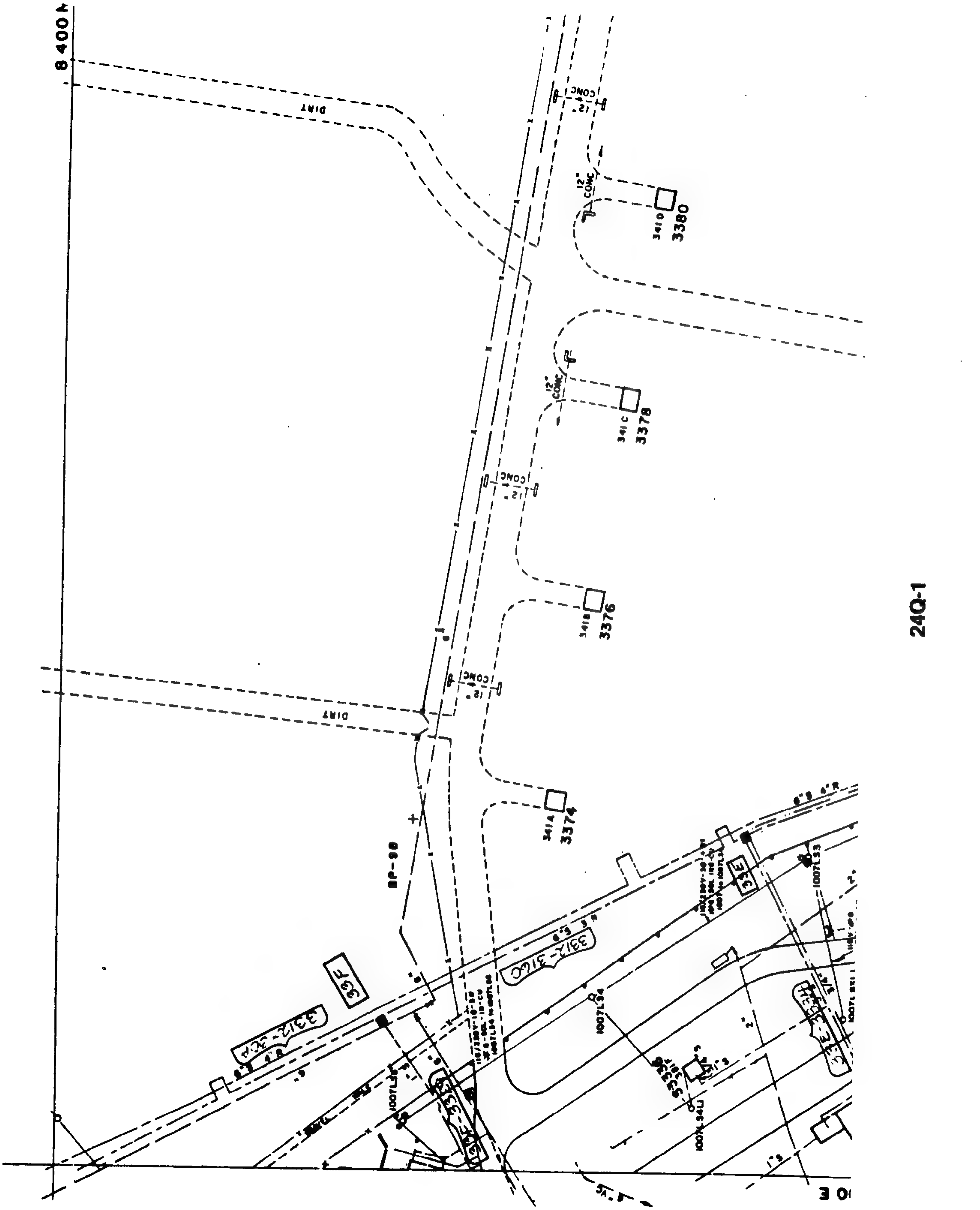
23P-4


PROPANE TANKS
COOLING TOWER
OIL TANK
3302
EL 13.00
3300
3329
3336
3334
4-4 DUCTS
CHEM SEWER

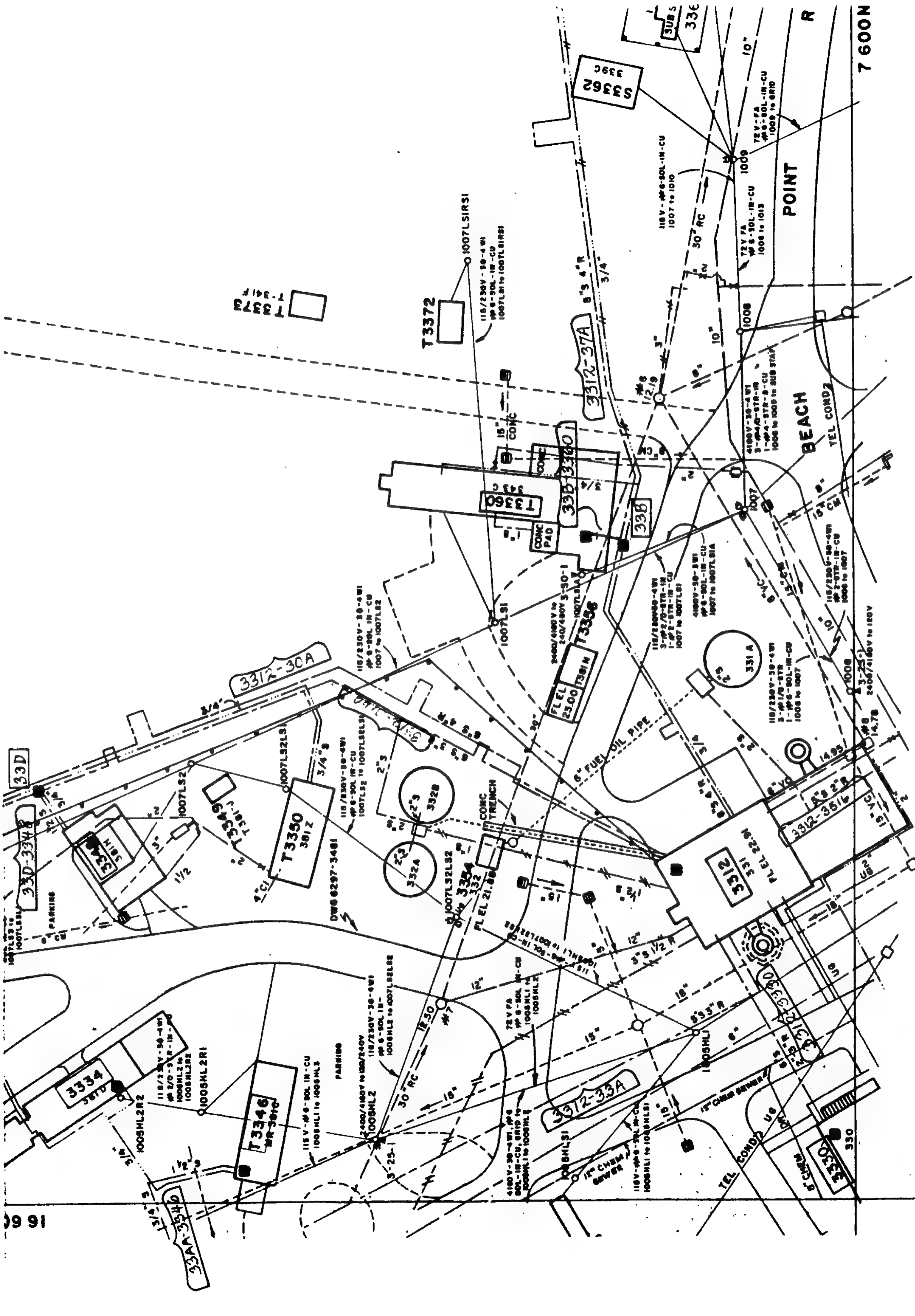
24P-2


52 ND
STREET
12" CHEM SEWER
3316
3315
3320
3330
330A
CONC PARKING
PARKING AREA
ROAD
UG ELEC S.L.
FIRE ANNUNCIATOR 3/4" CABLE (310)
FIRE ANNUNCIATOR 2" CONDUIT (310)

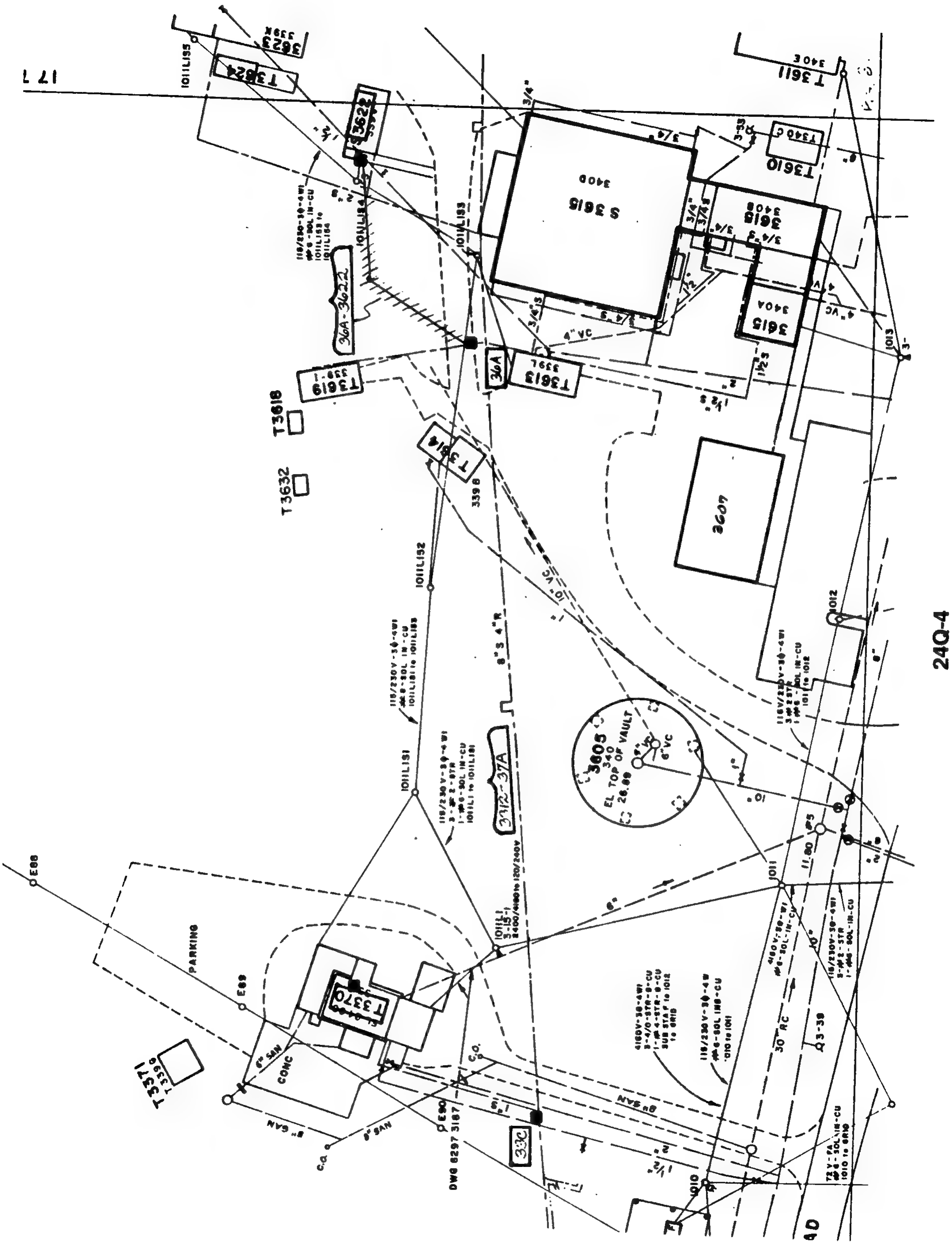
24P-4

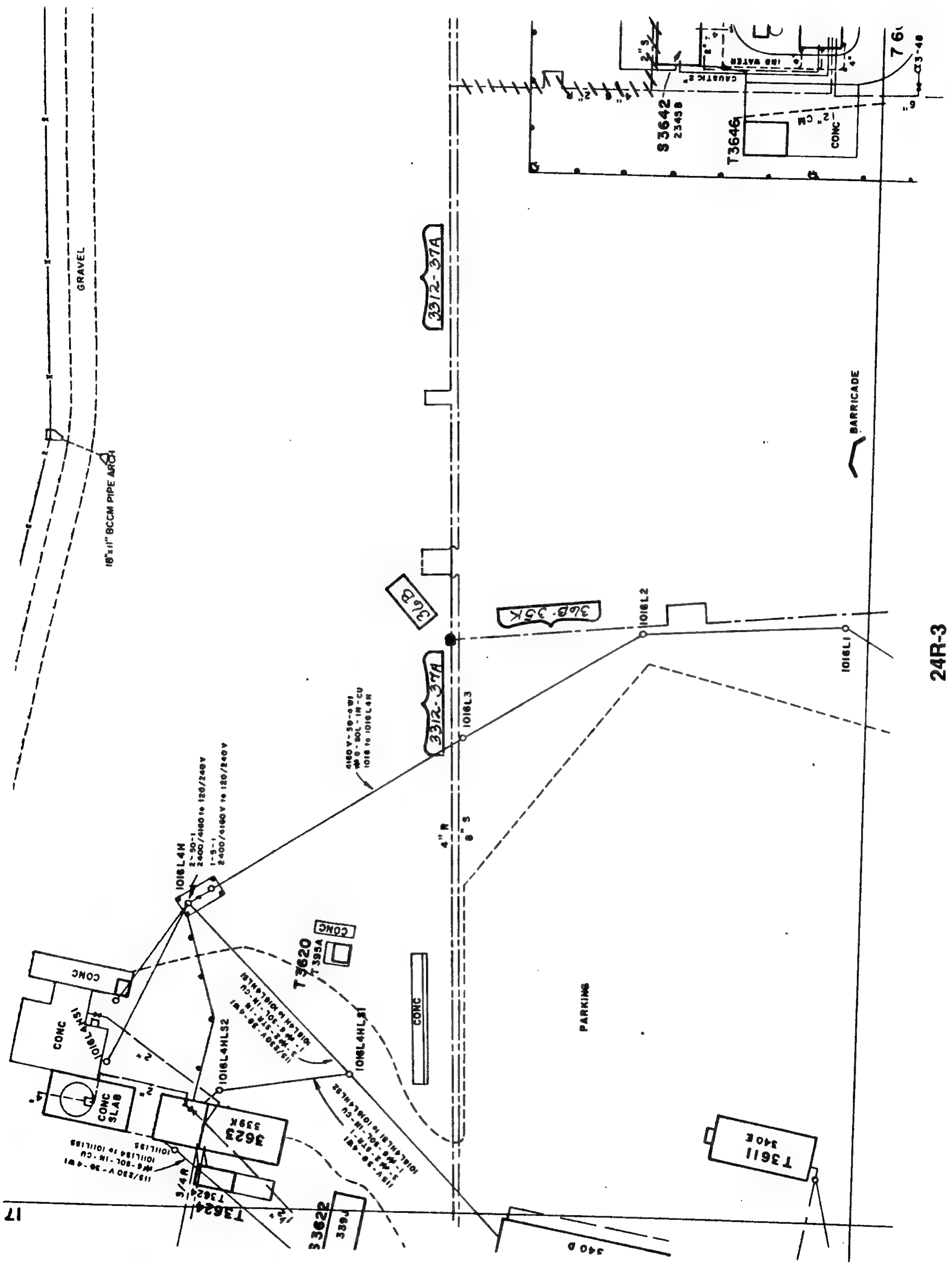

8 400 N
DIRT
12" CONC
341 D
3380
341 C
3378
341 B
3376
341 A
3374
BP-98
33F
3312-3CA
331X-316C
33E
1007L33
1007L34
1007L35
3 00 E

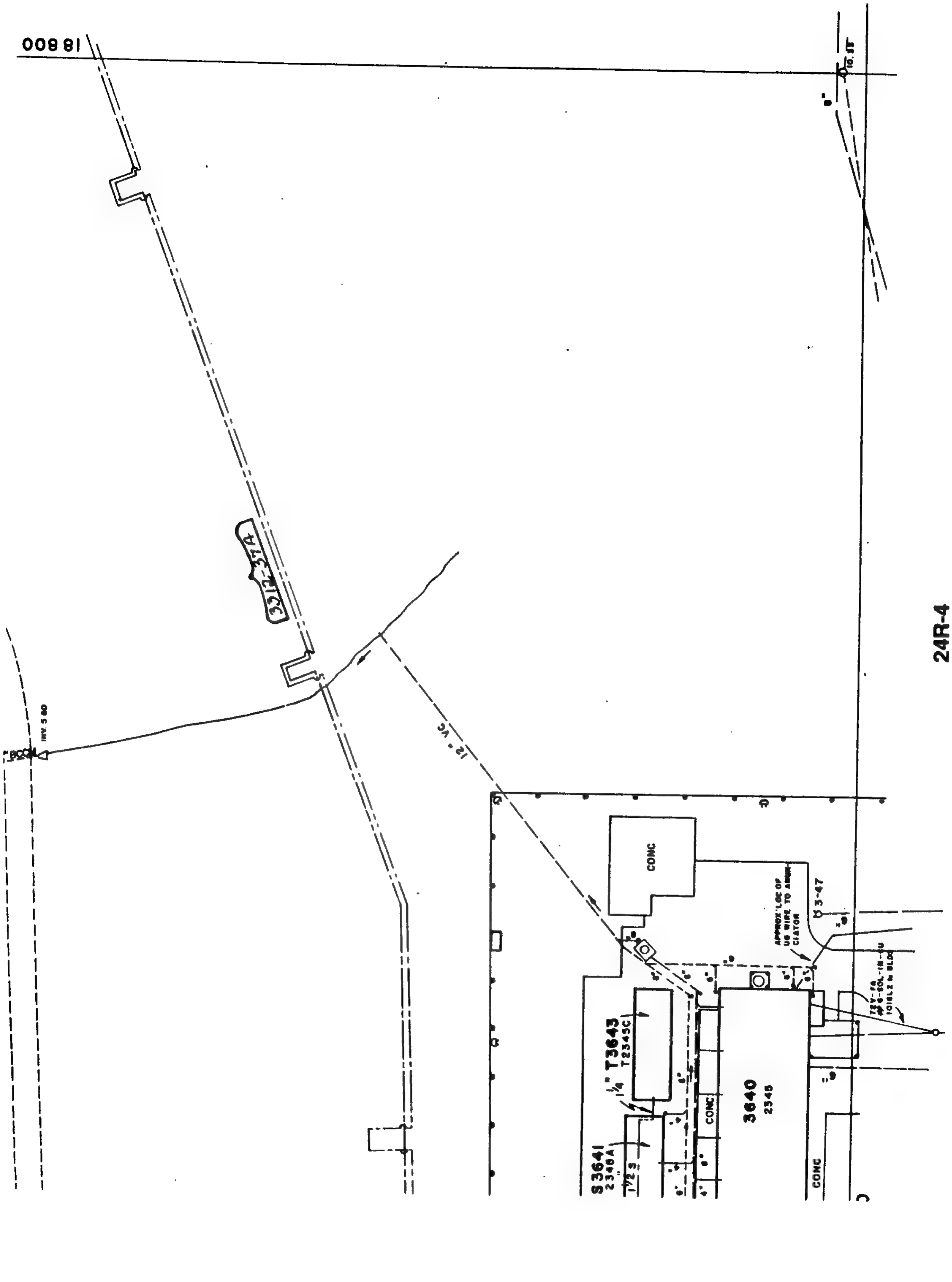
24Q-1

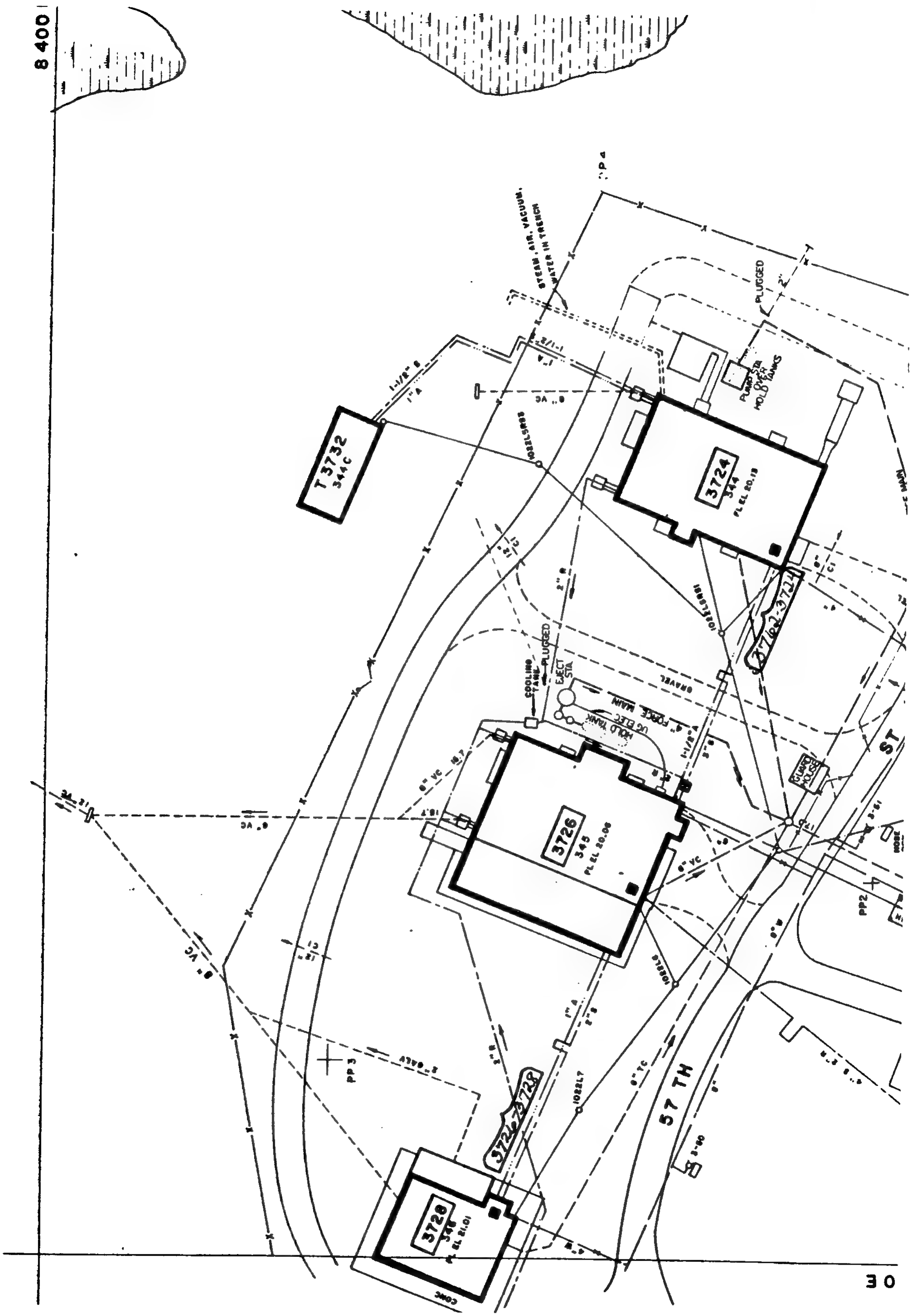

POINT
BEACH
7 600N
T3372
T3373
S3362
T3360
T3350
3312
T3346
3334
TEL COND
FUEL OIL PIPE
CONC TRENCH
PARKING
30" RC

24Q-3

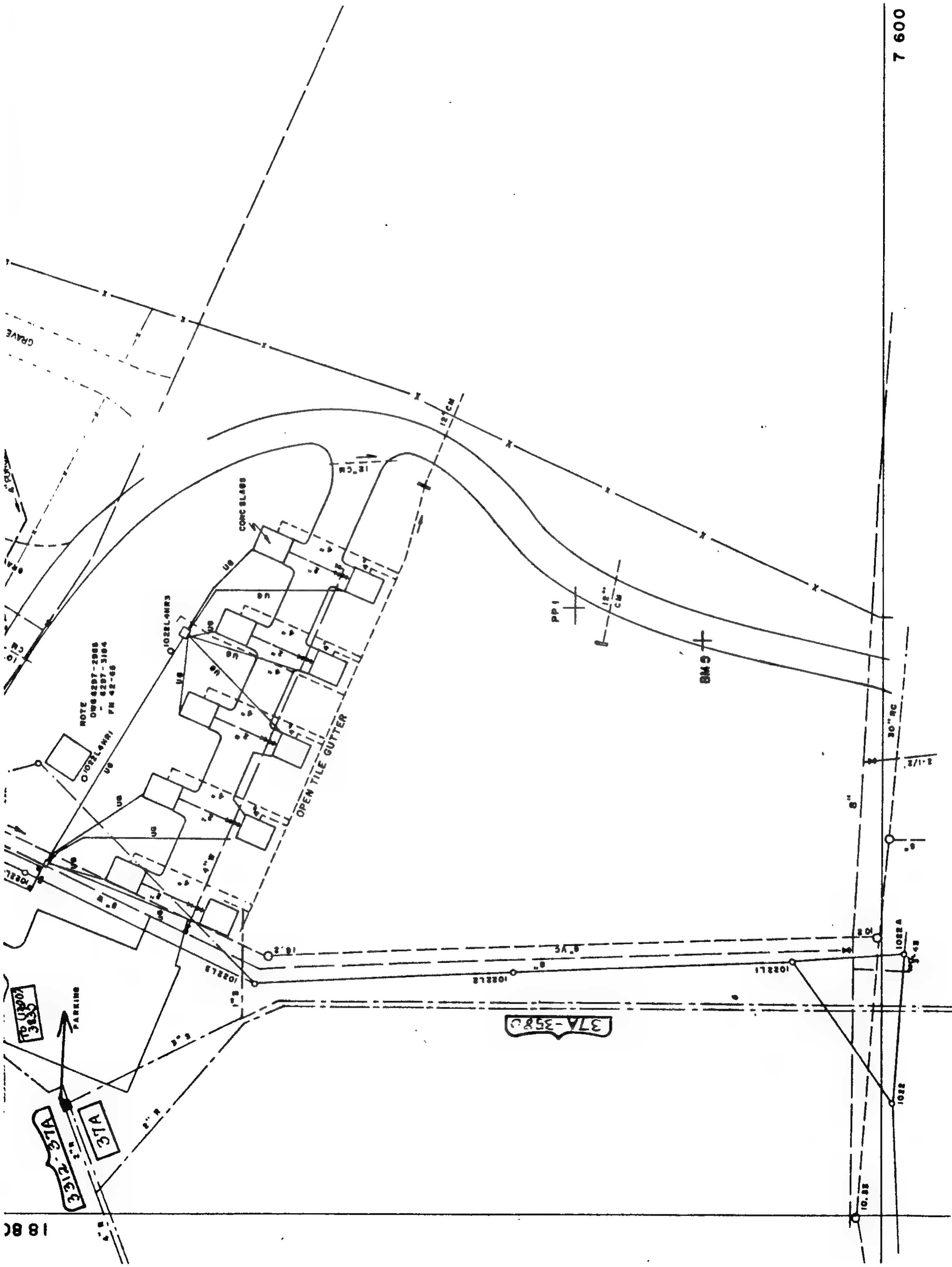

24Q-4
PARKING
3605
EL TOP OF VAULT
S 3615
3607
T3613
T3619
T3614
T3618
T3632
T3371
T3370
3615
3618
T3610
T 3611
3622
T 3624
3623
CONC
DWG 6297 3187

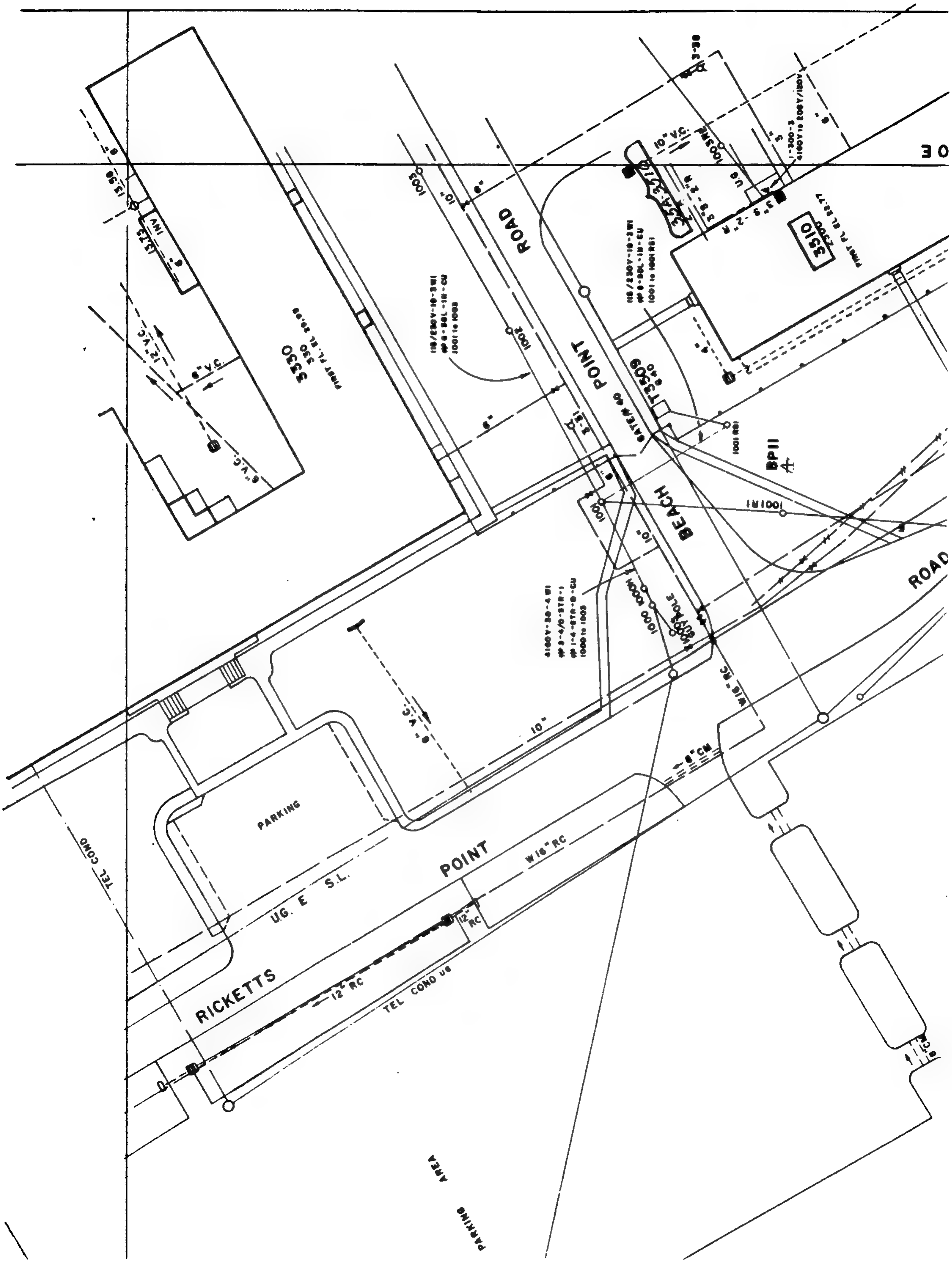

GRAVEL
18"x11" BCCM PIPE ARCH
3312-37A
36B
36B-35K
1016L2
1016L1
1016L3
1016L4H
PARKING
BARRICADE
CONC
CONC SLAB
T3620
3623
339K
T3611
340E
S3642
T3646
S3622
24R-3


24R-4
3640
2345
T3643
T2345C
S3641
CONC
CONC
CONC
CONC
3312-37A

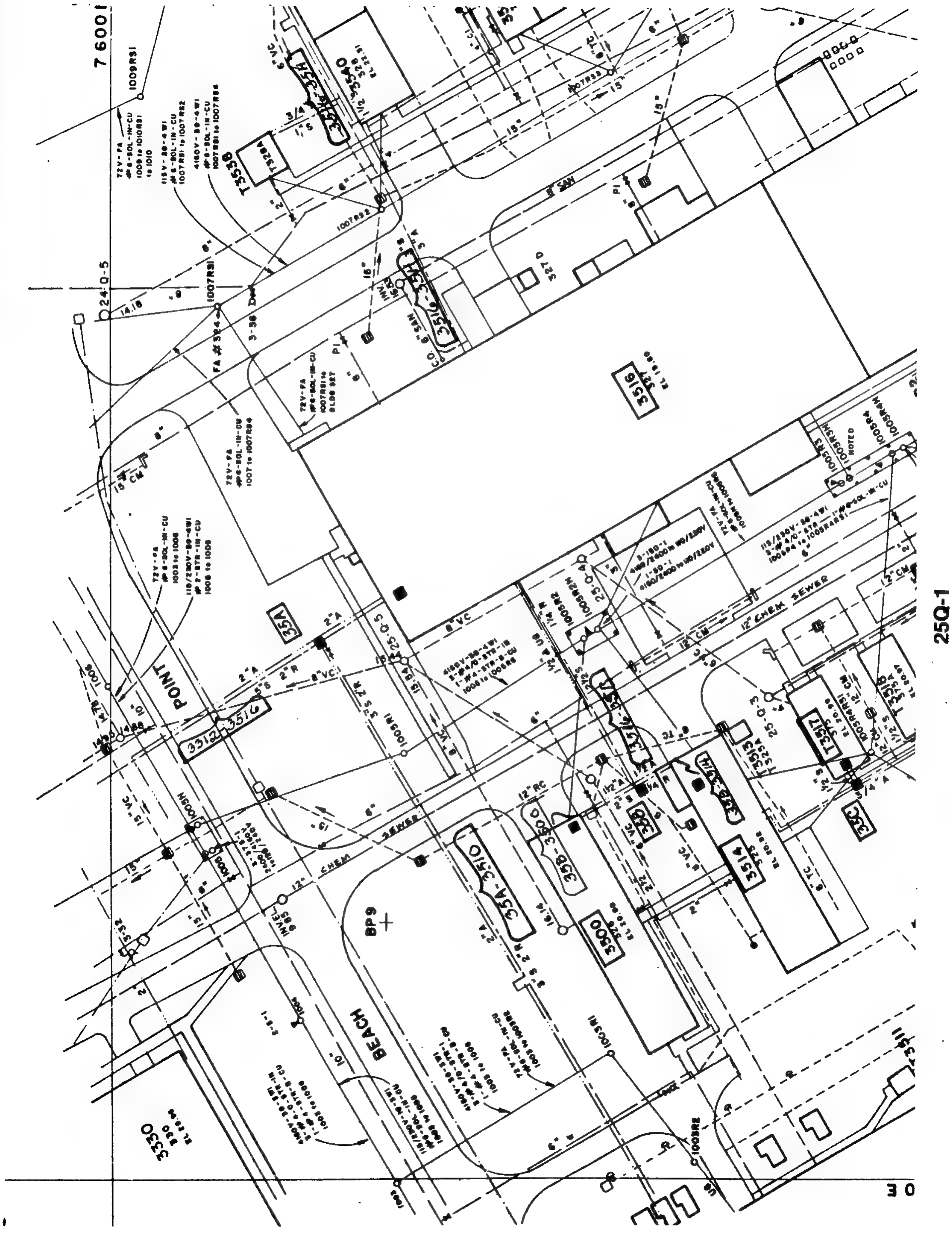

8 400
3 0
T 3732
344 C
3724
344
3726
345
3728
346
57 TH
ST
STEAM, AIR, VACUUM, WATER IN TRENCH
PLUGGED
PUMP STA OVER HOLD TANKS
COOLING TANK
EJECT STA
4" FORCE MAIN
UG ELEC
HOLD TANK
GRAVEL
GUARD HOUSE
PP2
PP 3

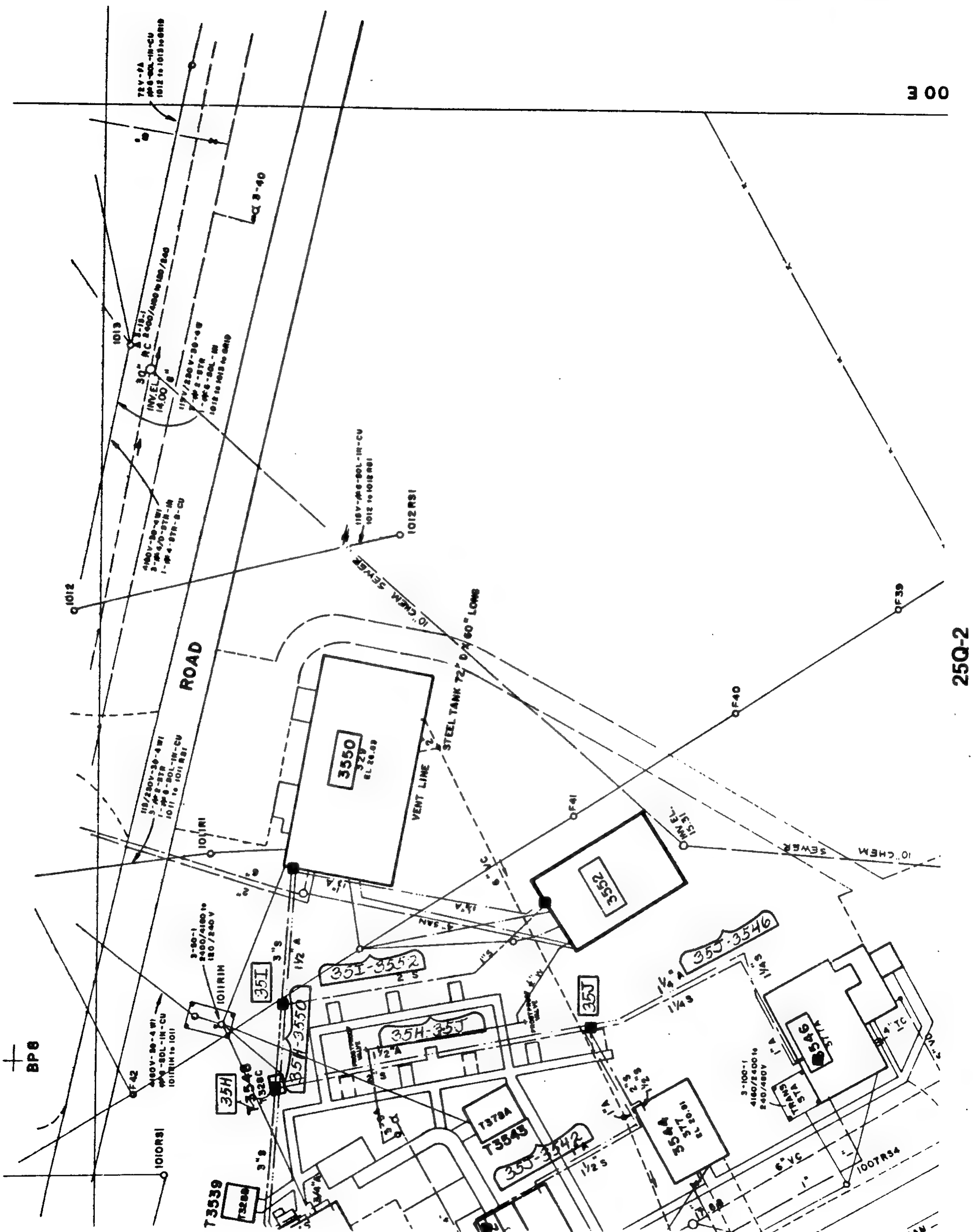
24S-1

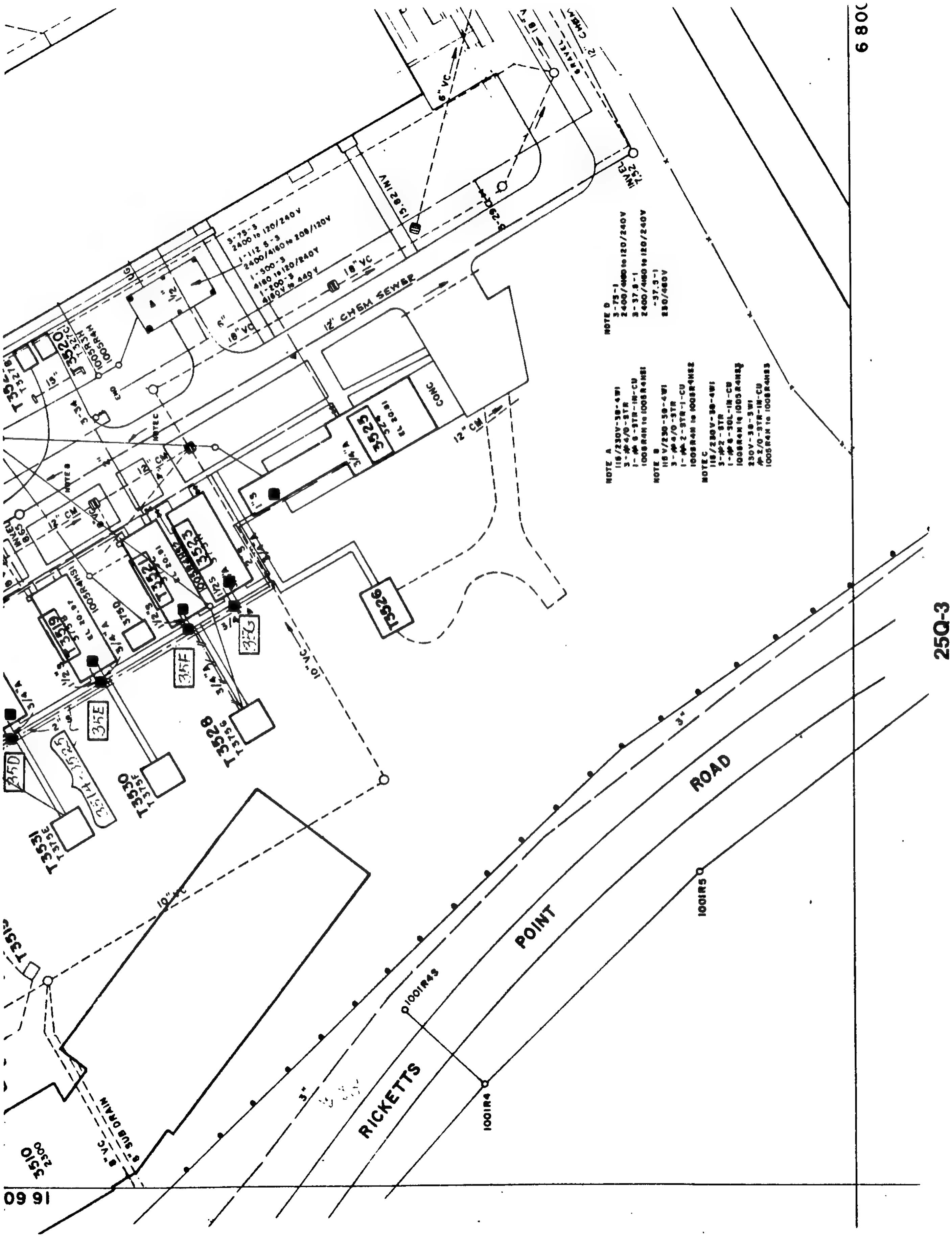

7 600
24S-3
OPEN TILE GUTTER
CONC SLABS
BM 5
PP 1
PARKING
37A
3312-37A

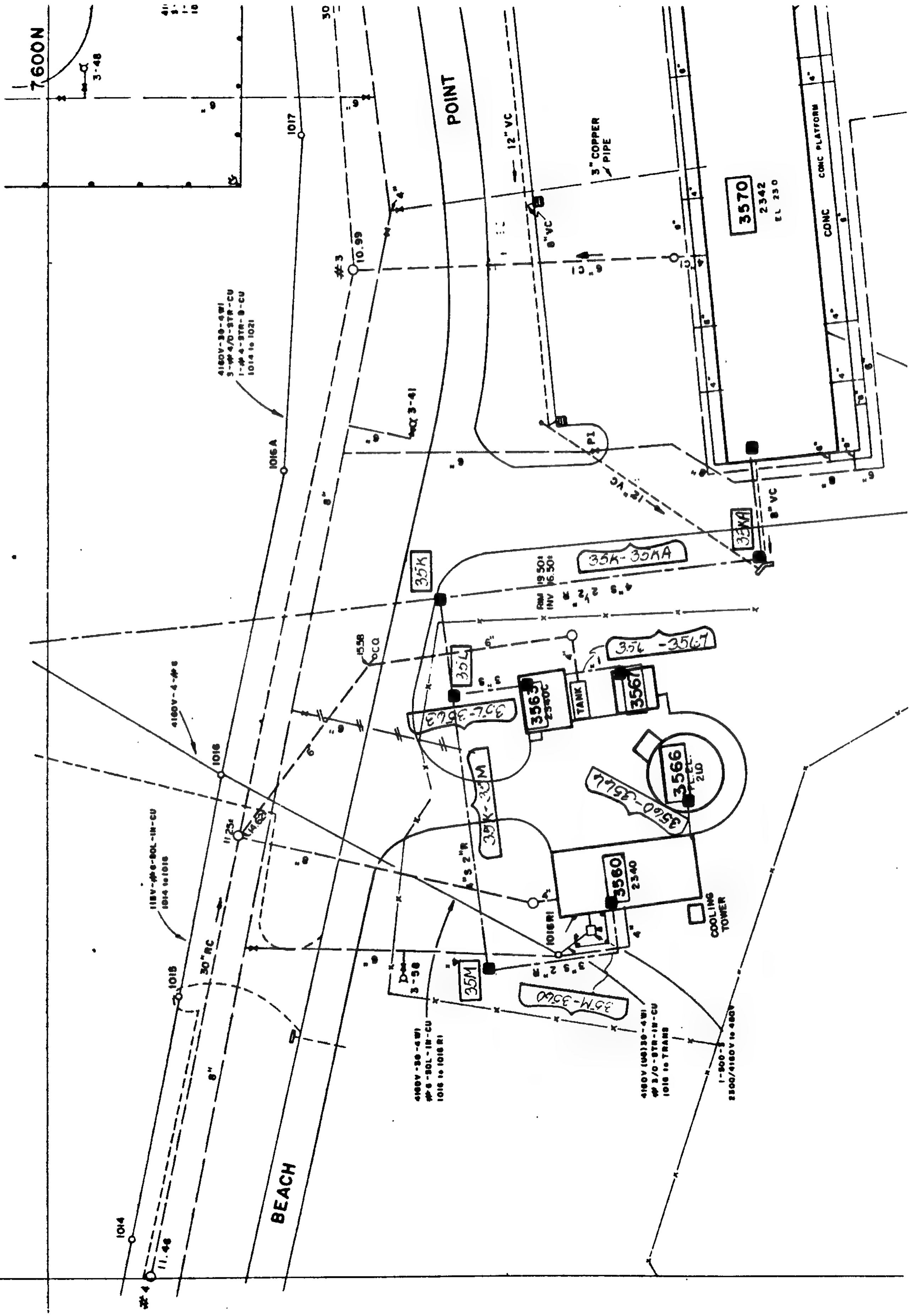

RICKETTS
POINT
ROAD
BEACH
POINT
ROAD
PARKING
PARKING AREA
3330
3510
UG. E S.L.
TEL COND
TEL COND UG
W16" RC
12" RC
BP11

25P-2

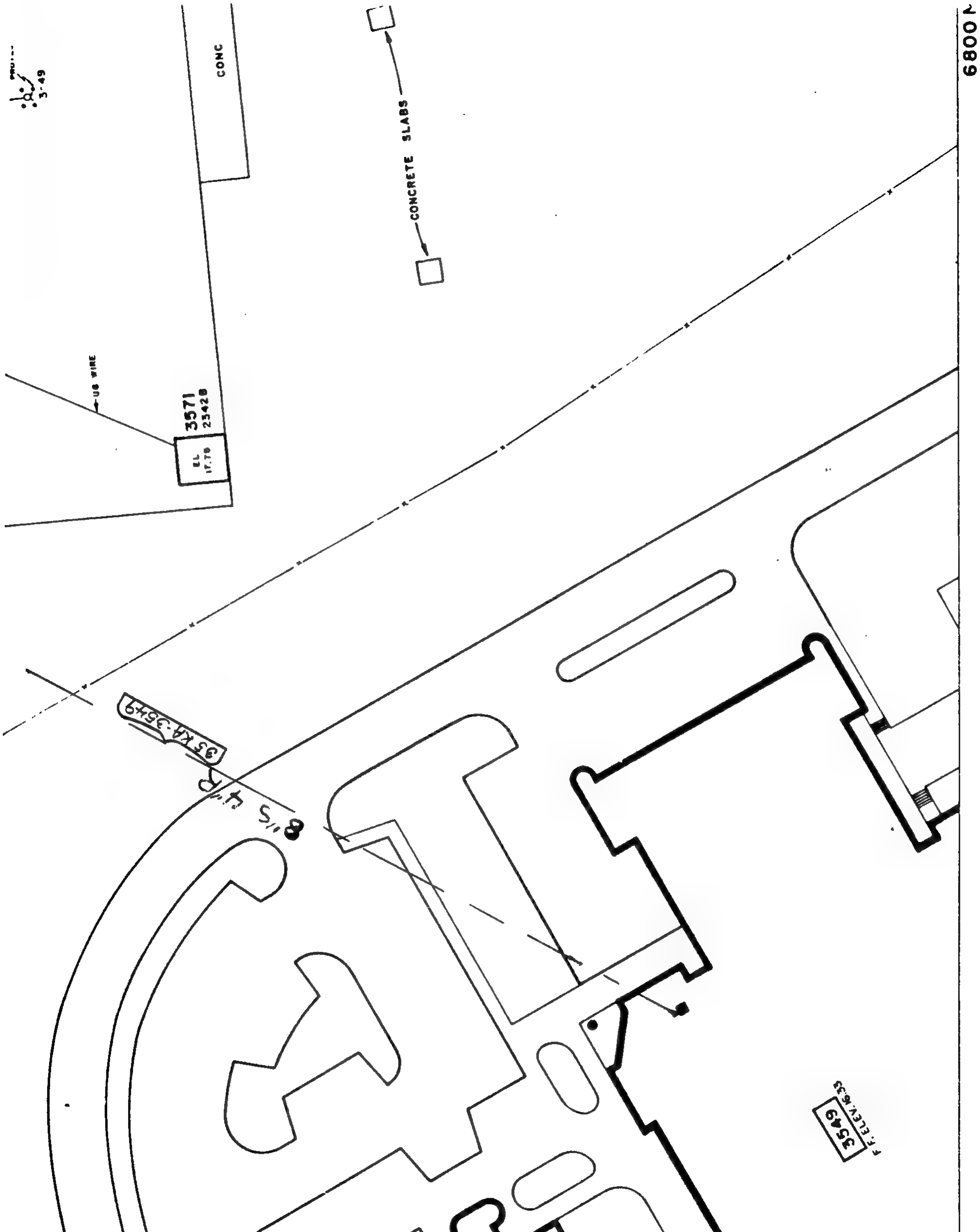

25Q-1
POINT
BEACH
3516
35A
3500
3514
3510
3330
12" CHEM SEWER


3 00
25Q-2
ROAD
3550
3552
VENT LINE
STEEL TANK 72" D x 60" LONG
10" CHEM SEWER
F39
F40
F41
F42
BP 8
35H
35I
35J
35I-3552
35H-35J
35J-3546
T3543
T3539
1012
1013
1012 RSI
1011 RSI
1010 RSI

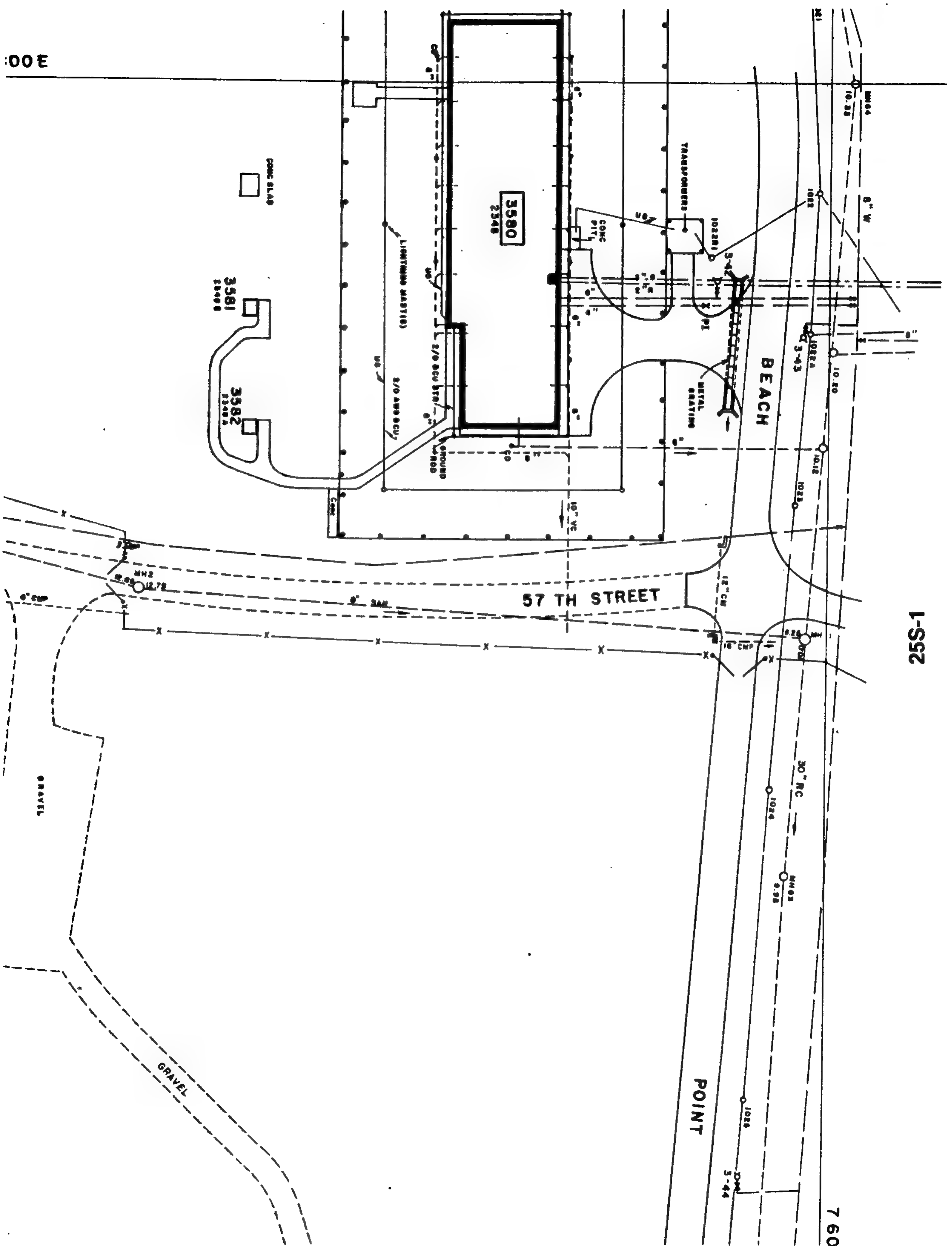

RICKETTS
POINT
ROAD
12" CHEM SEWER
T3526
T3528
T3530
T3531
3525
3523
T3520
1001R4
1001R43
1001R5
25Q-3
09 91
6 80


7600N
POINT
BEACH
12" VC
3" COPPER PIPE
3570
2342
CONC PLATFORM
CONC
35K
35K-35KA
35KA
8" VC
35L
35L-3567
3567
3563
TANK
35L-3563
35K-35M
3566
3560-3566
3560
2340
COOLING TOWER
35M
35M-3560
30" RC
BEACH
1014
1016
1016 A
1017
1018
#3
#4
10.99
11.46

25R-1

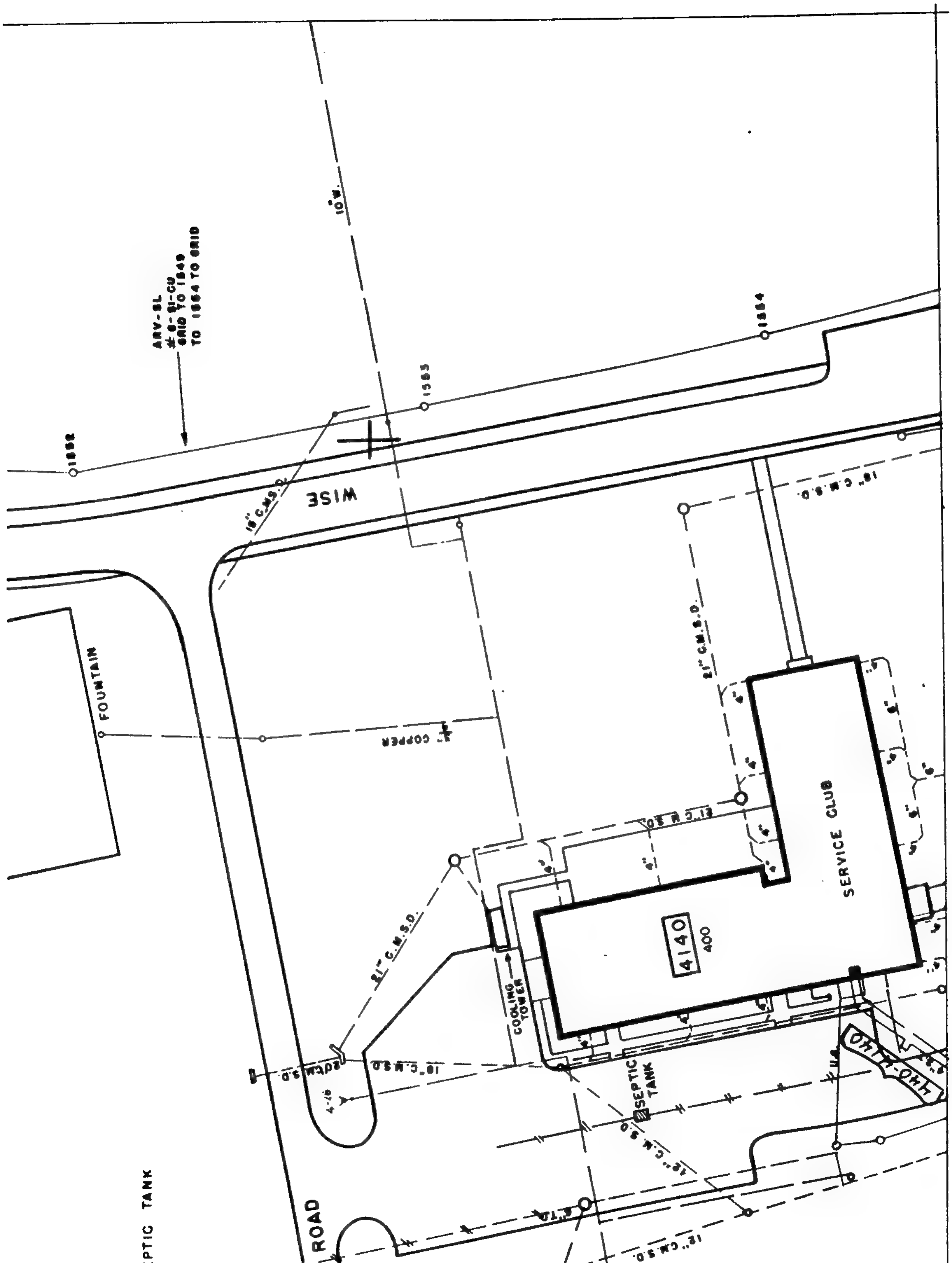

CONC
CONCRETE SLABS
US WIRE
3571
23428
EL 17.76
6800 N
17 700 E
35KA-3549
3549
F.F. ELEV 16.33
3549
F.F. ELEV 16.33

25R-3

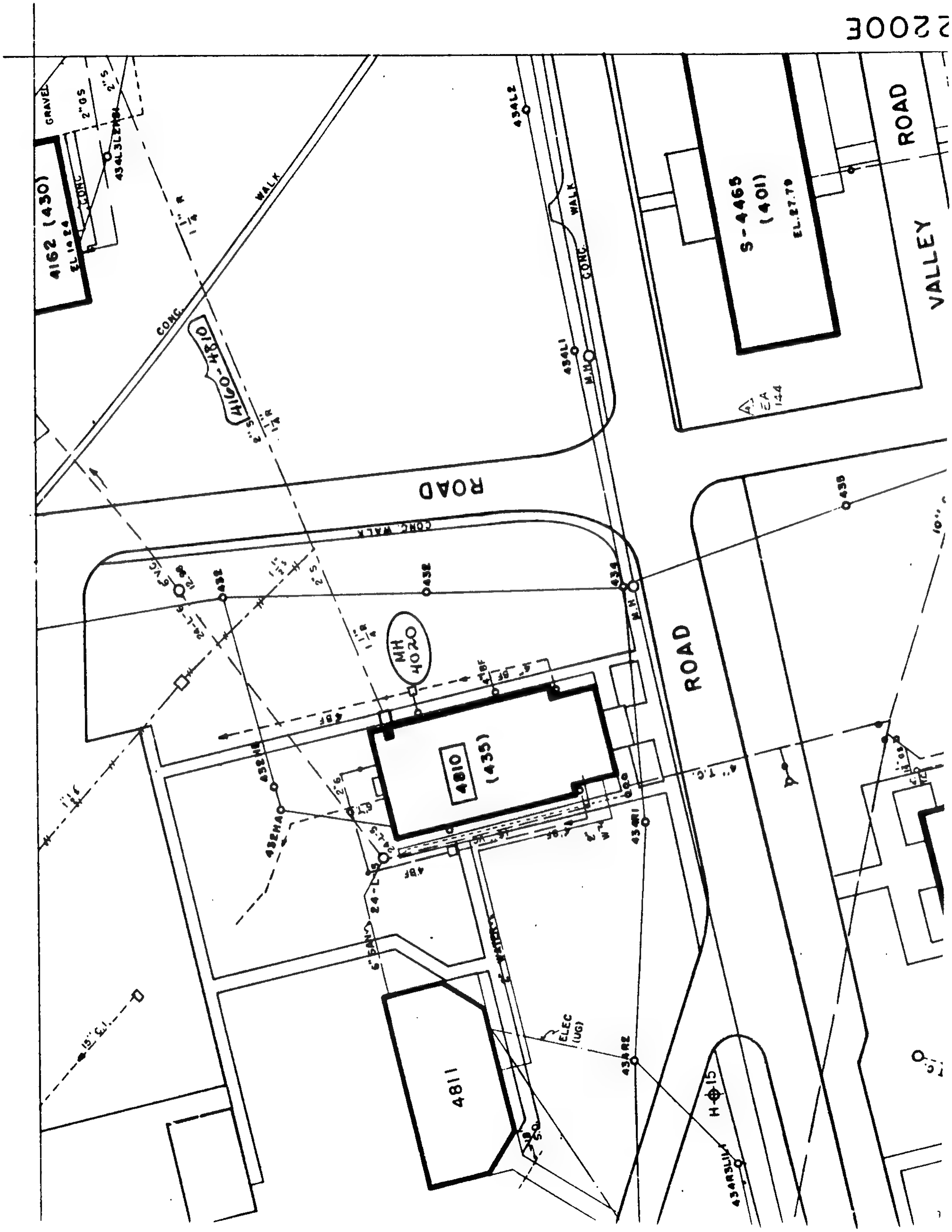

3580
2346
3581
3582
57 TH STREET
BEACH
POINT
GRAVEL
TRANSFORMERS
LIGHTNING MAST(S)
METAL GRATING
CONC PIT
CONC SLAB
MH2
30"RC
8" SAN
25S-1
7 60
00 E

Layout Chart for 4000 Area Quadrant Map Sheets

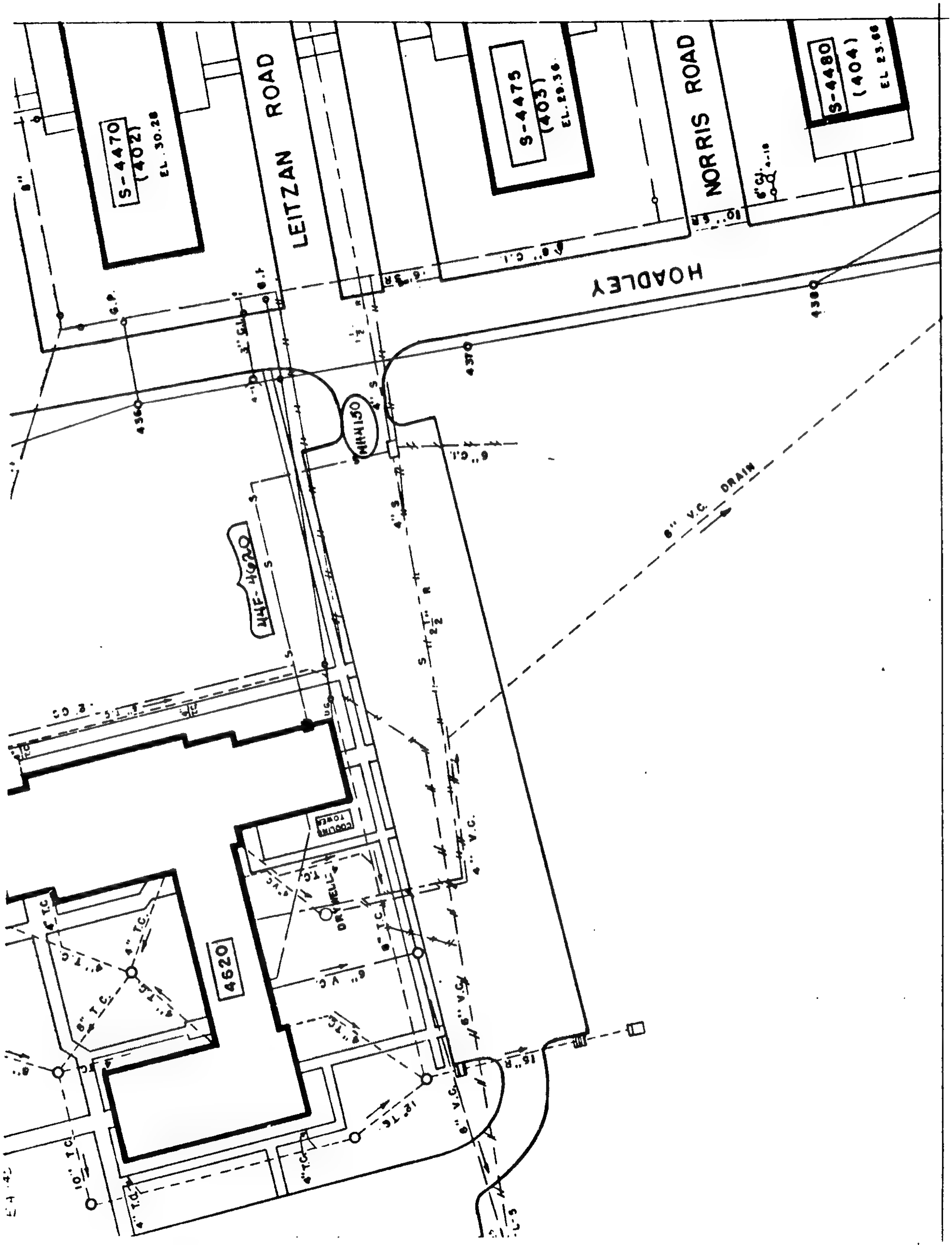
		23M-4		
24L-2	24M-1	24M-2	24N-1	24N-2
24L-4	24M-3	24M-4	24N-3	


WISE
ROAD
FOUNTAIN
SERVICE CLUB
4140
400
COOLING TOWER
SEPTIC TANK
21" C.M.S.D.
18" C.M.S.D.
2" COPPER
10"W.

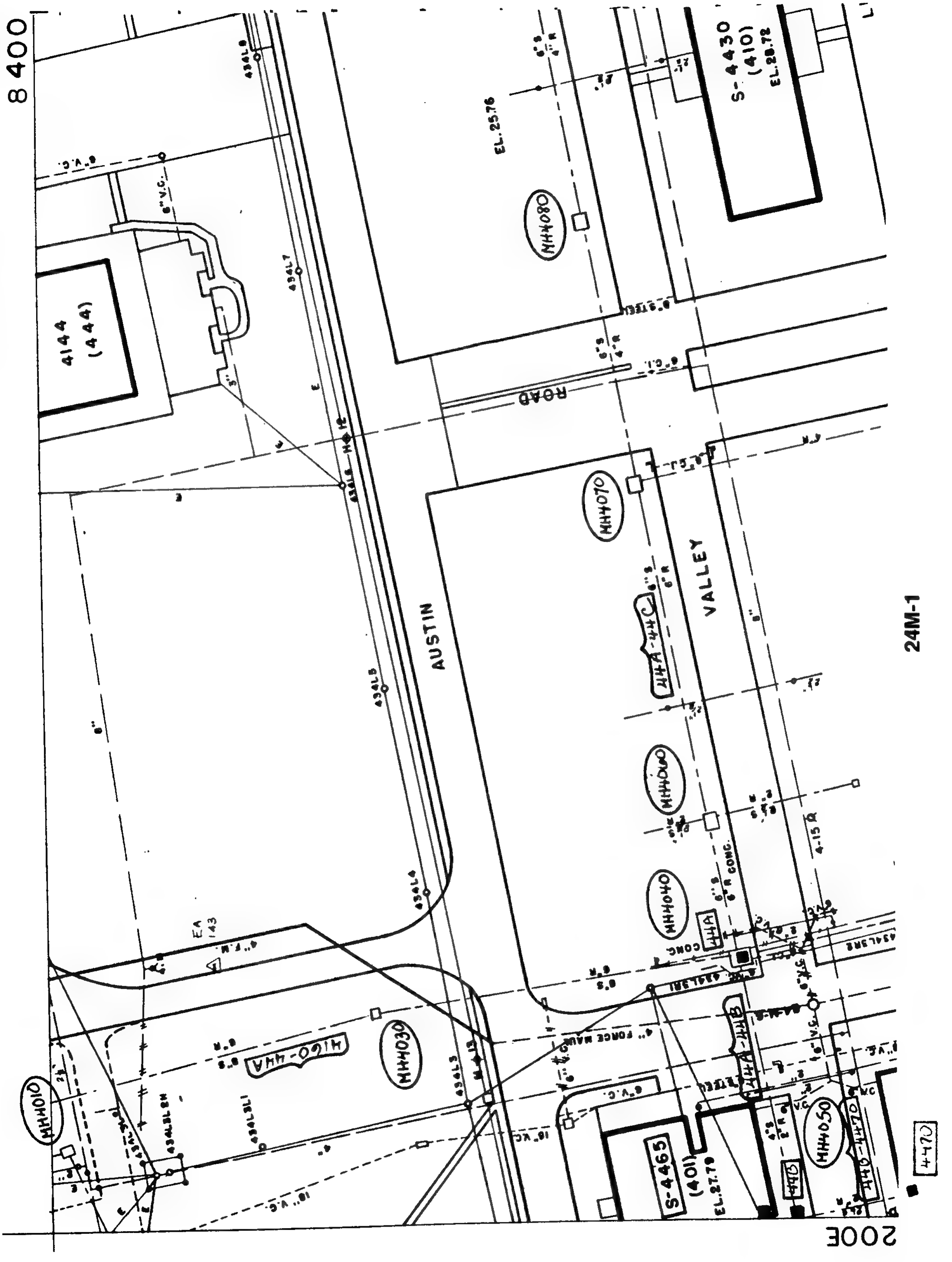
23M-4


4162 (430)
S-4465
(4011)
4810
(435)
4811
MH
4020
4160-4810
VALLEY
ROAD
ROAD
ROAD
WALK
CONC.
CONC. WALK
GRAVEL
ELEC
(UG)
M.H.
H-15

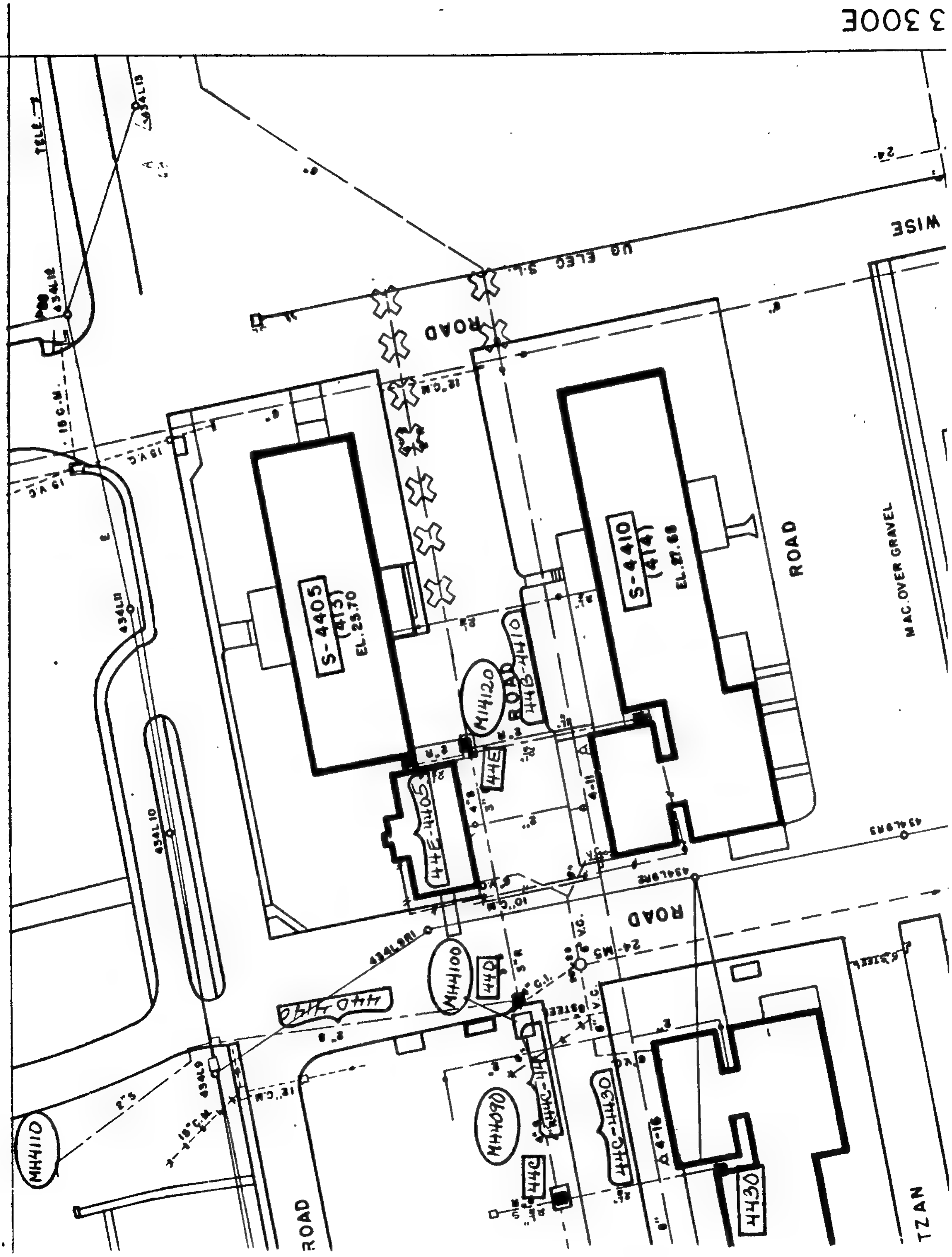
24L-2


LEITZAN ROAD
NORRIS ROAD
HOADLEY
S-4470
(402)
S-4475
(403)
S-4480
(404)
4620
MH4150
44F-4620
COOLING TOWER
DRYWELL
6" V.C. DRAIN

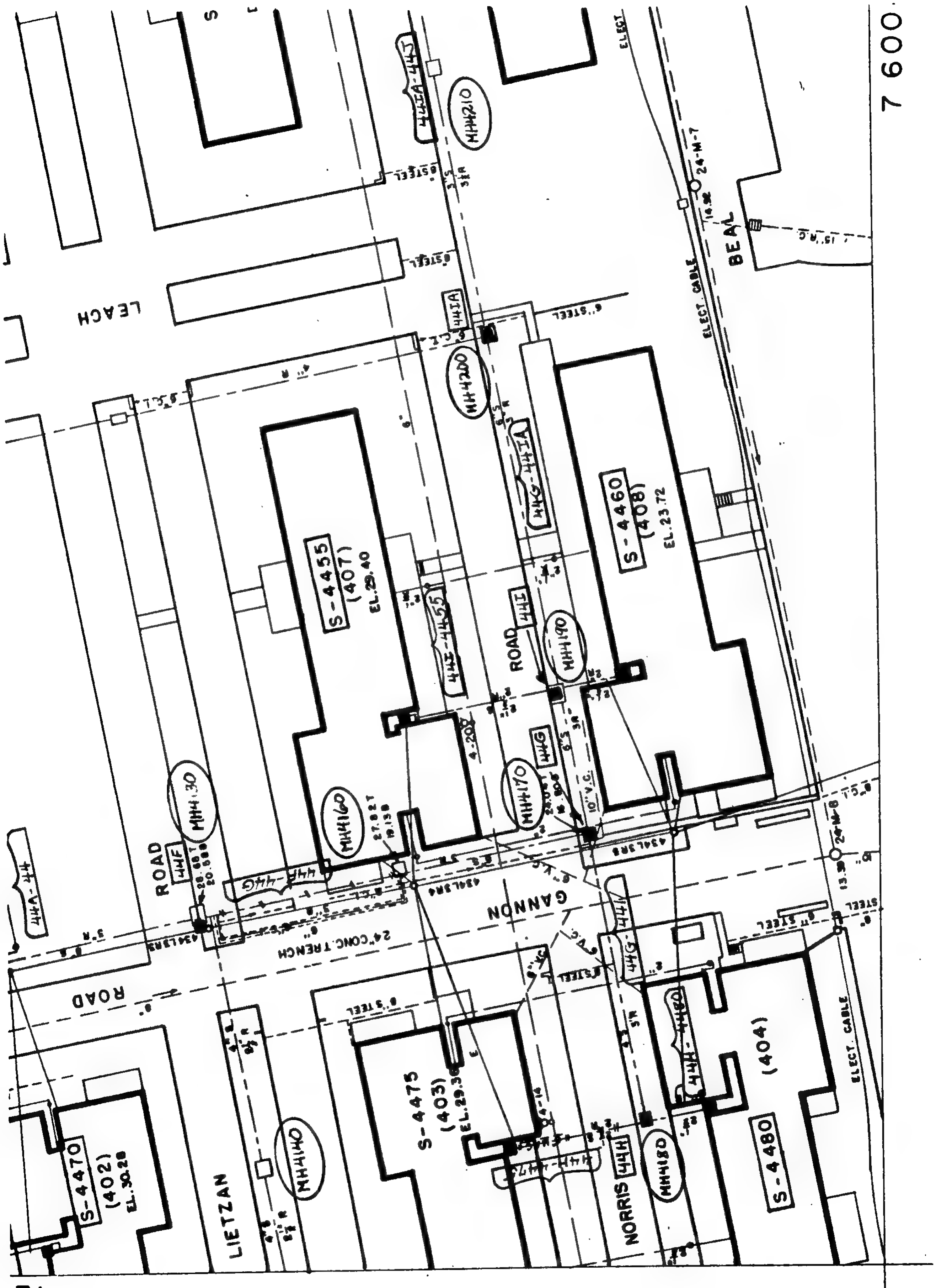
24L-4


8 400
200E
4144
(444)
S-4430
(410)
EL. 28.72
EL. 25.76
S-4465
(401)
EL. 27.79
AUSTIN
ROAD
VALLEY
MH4010
MH4030
MH4040
MH4050
MH4060
MH4070
MH4080
H160-44A
44A-44C
44A-44B
44A
44B
440-4470
4470

24M-1


3 300E
WISE
UG ELEC
ROAD
S-4405
(413)
EL. 25.70
S-4410
(414)
EL. 27.68
MAC. OVER GRAVEL
MH4120
MH4100
MH4090
MH4110
44E
44D
44C
4430
TZAN

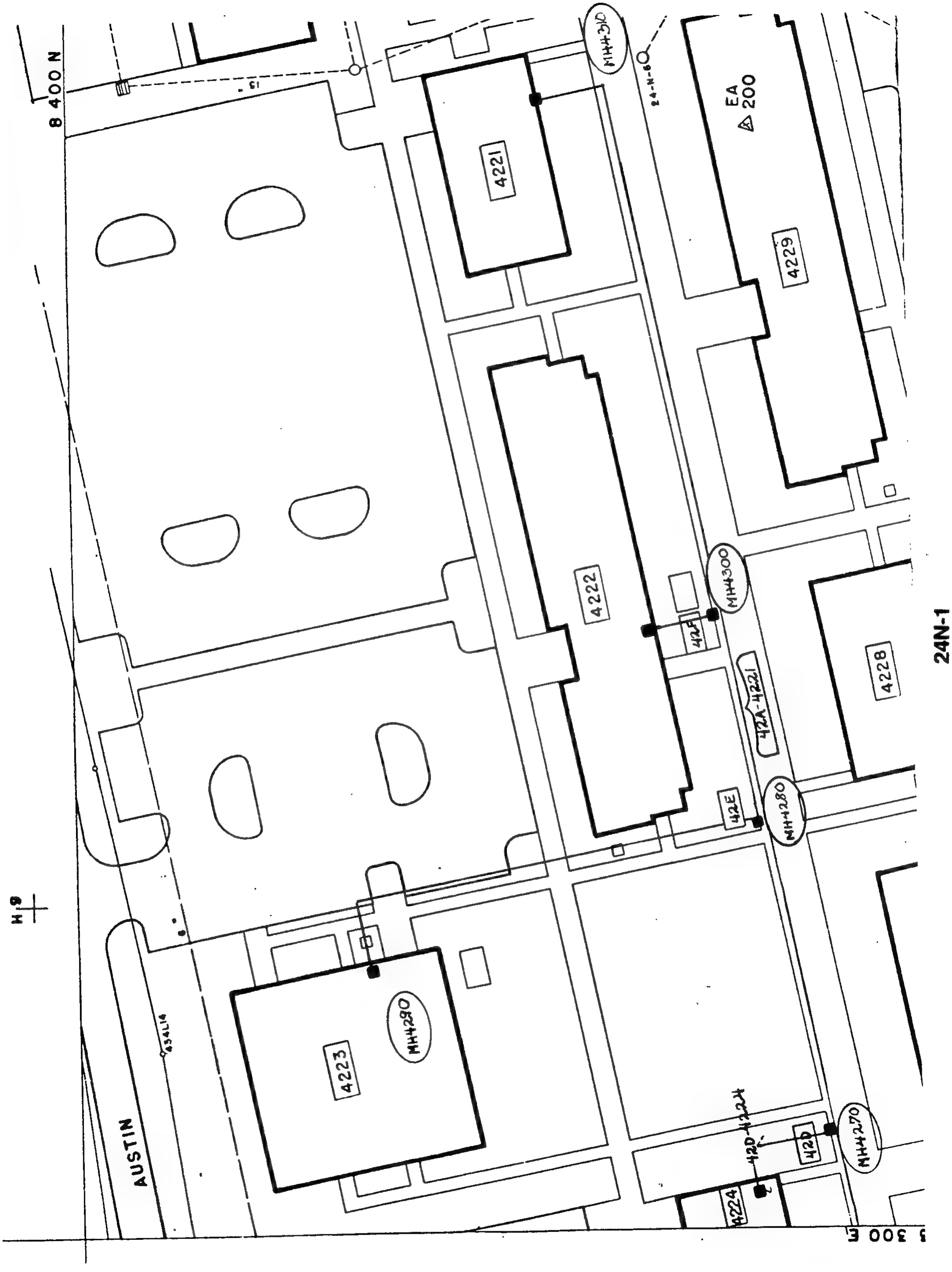
24M-2

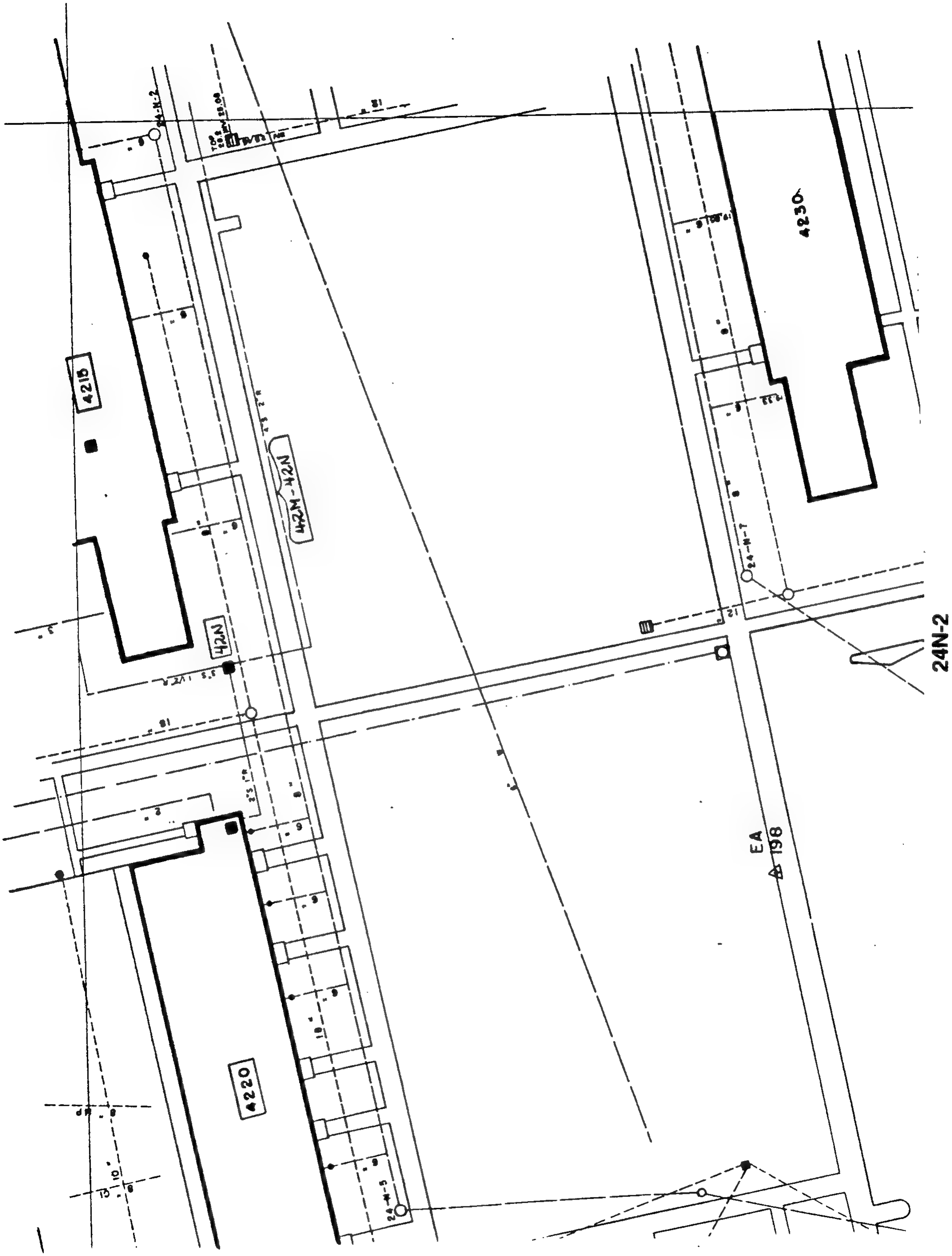

7600
LEACH
BEAL
ROAD
GANNON
ROAD
NORRIS
LIETZAN
ELECT. CABLE
24"CONC. TRENCH
S-4455
(407)
EL.29.40
S-4460
(408)
EL.23.72
S-4475
(403)
EL.29.36
(404)
S-4480
S-4470
(402)
EL.30.28
MH4130
MH4140
MH4160
MH4170
MH4180
MH4190
MH4200
MH4210
44F
44G
44H
44I
44IA
24-M-7
24-M-8
12

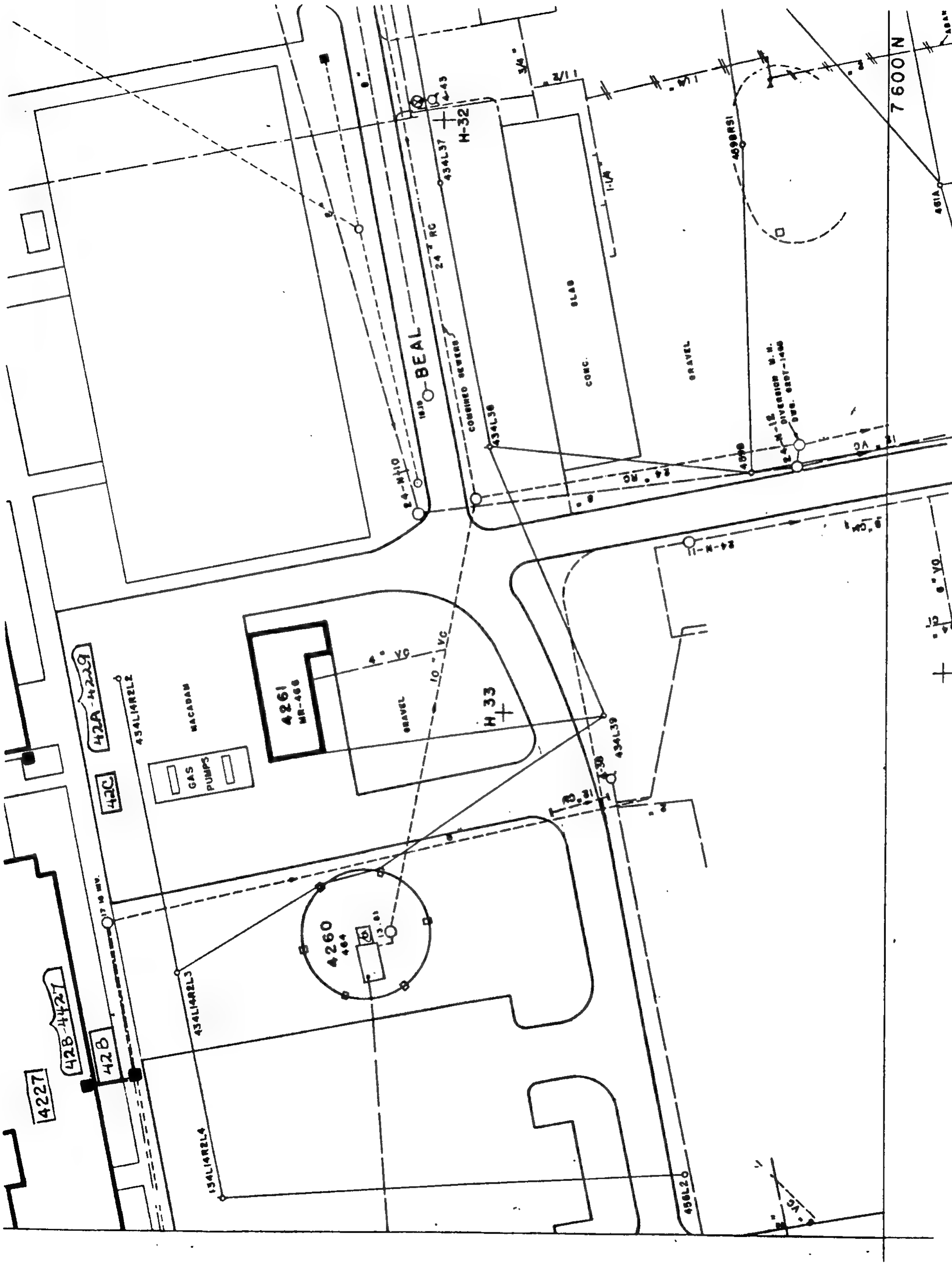
24M-3


MH4260
42A
S-4415
(415)
EL. 28.80
S-4420
(416)
EL. 25.60
AERIAL
CONC.
ROAD
MH4250
ELECT. CABLE
SIREN
T-4491
T-4490
(T-14437)
MH4240
MH4230
MILES
44K
44M
BRICK PARKING
NORRIS
MH4220
44J
S-4440
(412)
EL. 27.35
4435

24M-4

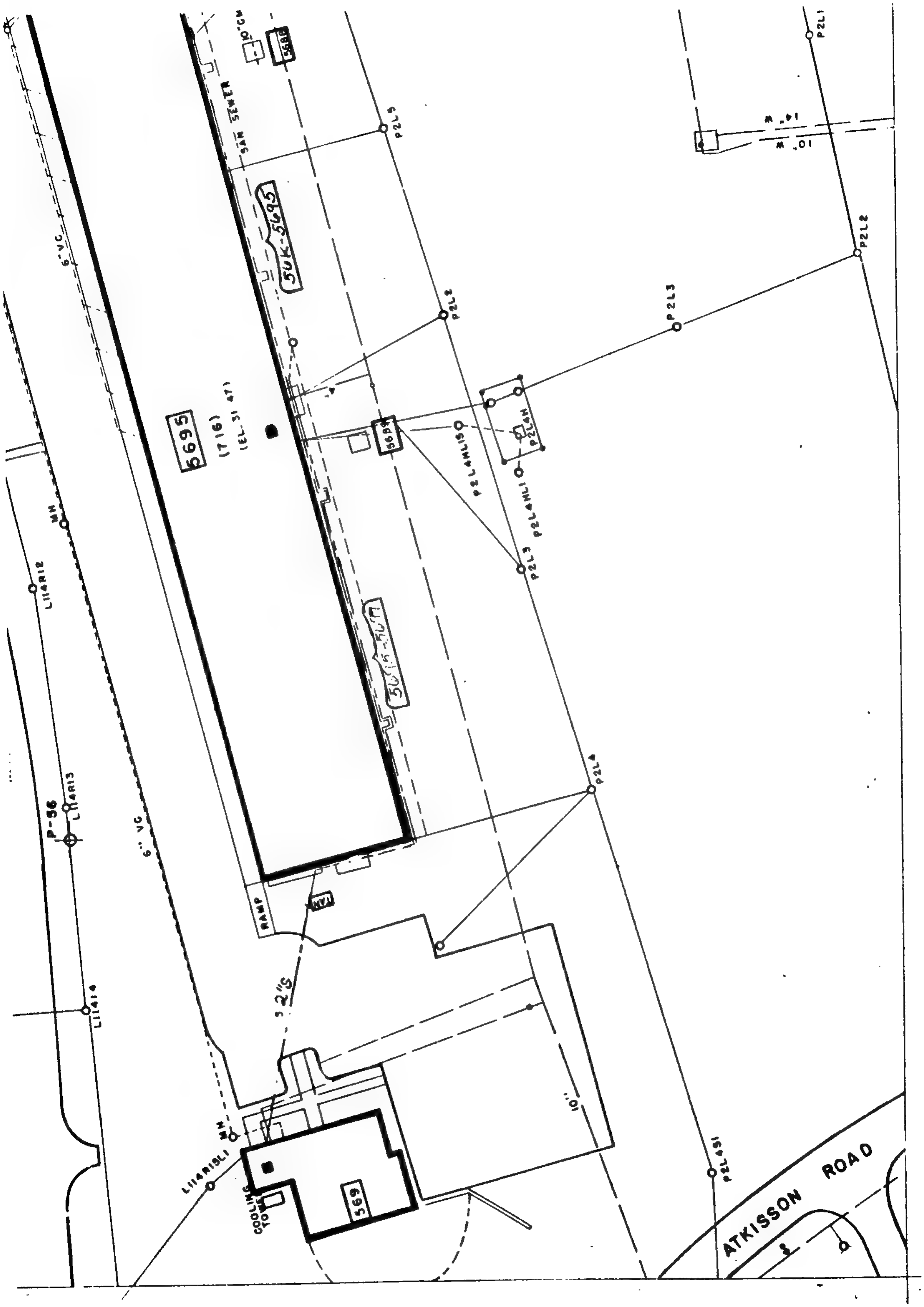

8 400 N
MH4310
EA
200
4221
4229
4222
MH4300
42F
42A-4221
4228
24N-1
42E
MH4280
4223
MH4280
AUSTIN
42D-4224
42D
MH4270
4224
300 E


4215
42N-42N
42N
4220
4230
EA
198
24N-2

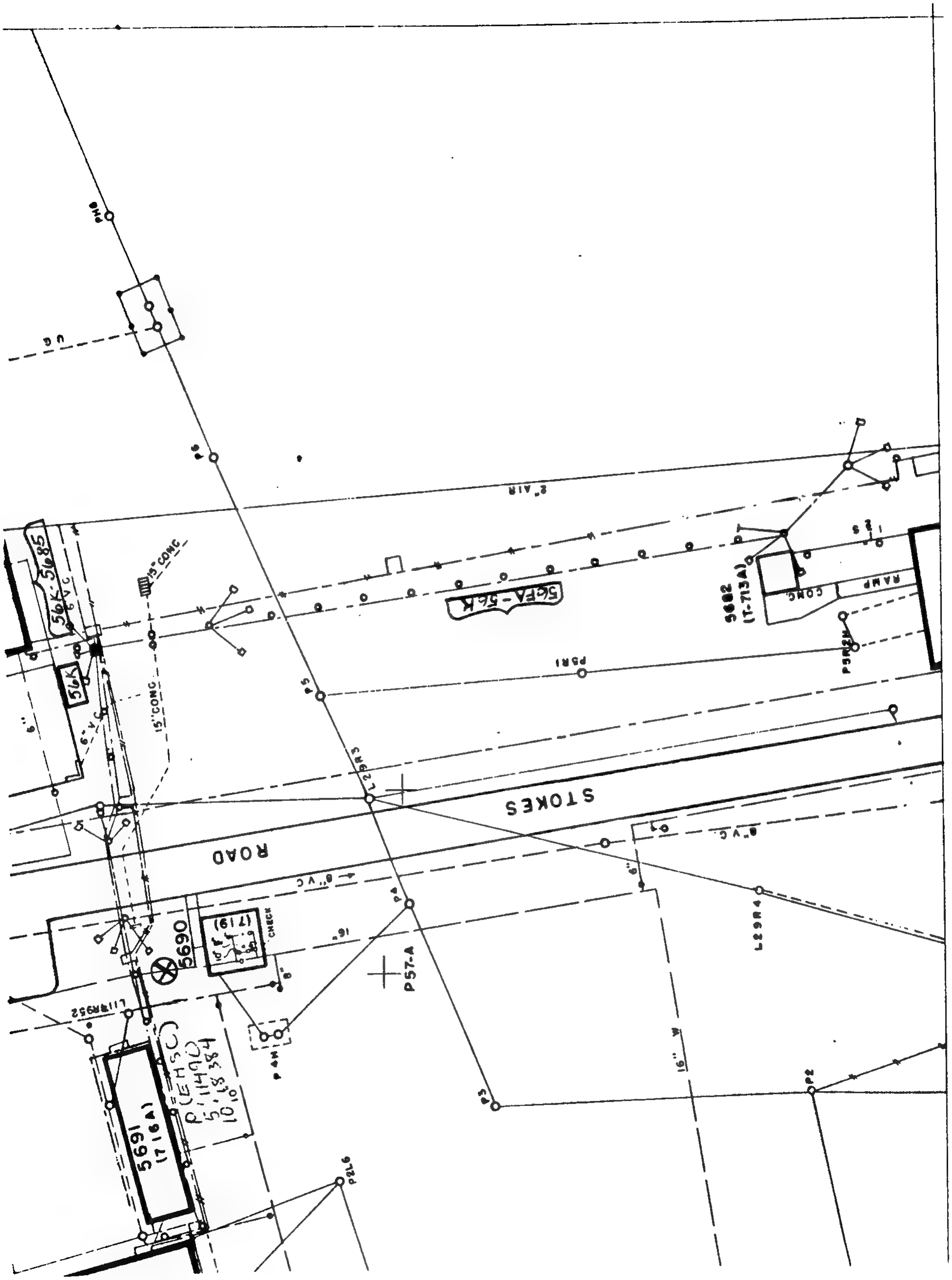

BEAL
COMBINED SEWERS
24" RC
H-32
434L37
434L36
24-N-10
CONC.
SLAB
GRAVEL
7 600 N
461A
459A
4261
MR-466
4" VC
10" VC
GRAVEL
MACADAM
GAS
PUMPS
H 33
434L39
4260
464
434L14R2L2
434L14R2L3
134L14R2L4
456L2
42A-4229
42C
42B-4427
42B
4227
24-N-11
6" VC
H-118B
24N-3

Layout Chart for 5000 Area Quadrant Map Sheets

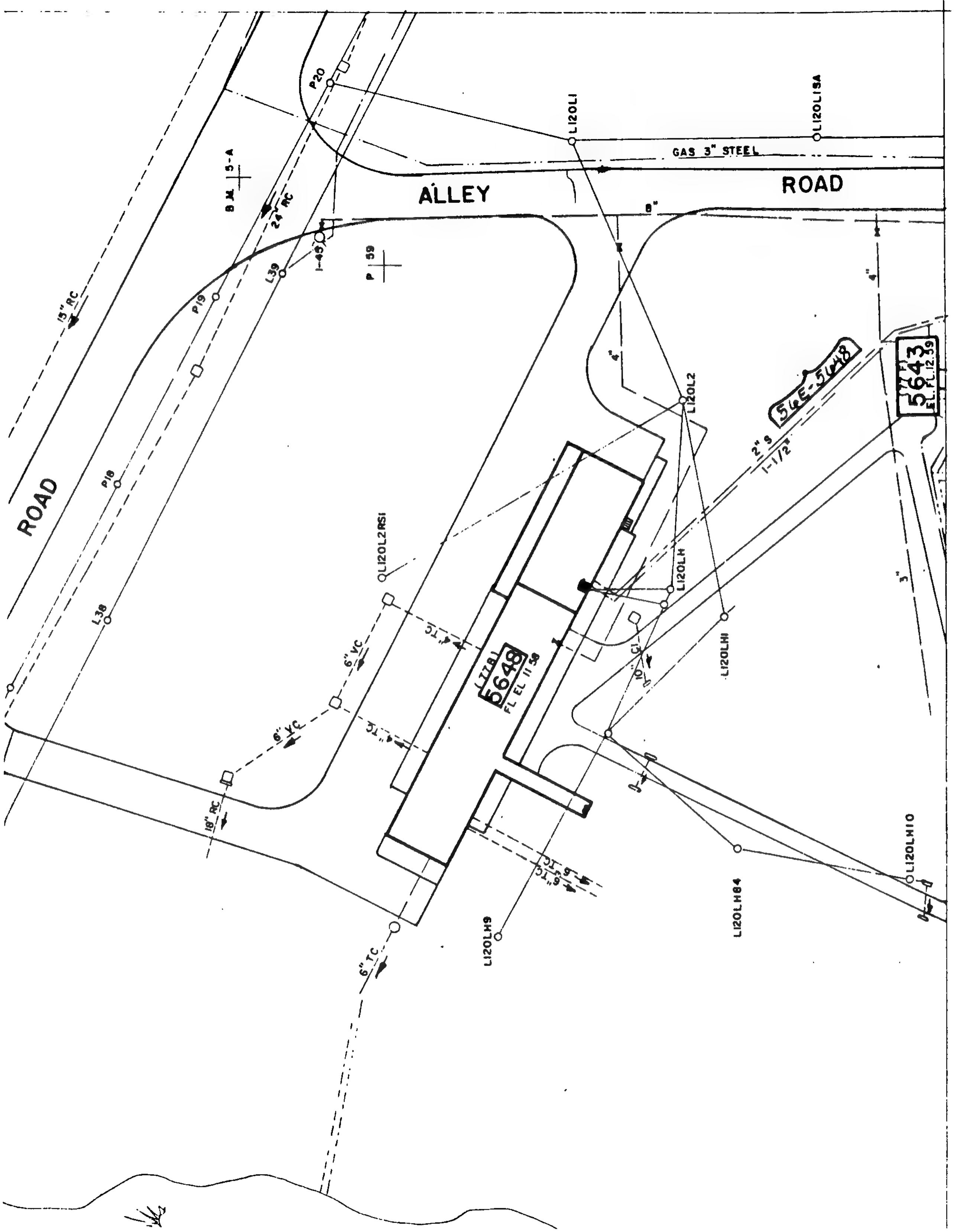
				17L-1					
17J-3	17J-4		17K-4	17L-3					
	18J-2	18K-1	18K-2	18L-1	18L-2				
		18K-3		18L-3	18L-4	18M-3	18M-4		
		19K-1	19K-2	19L-1	19L-2	19M-1	19M-2	19N-1	19N-2
		19K-3	19K-4	19L-3		19M-3	19M-4	19N-3	19N-4
				20L-1	20L-2	20M-1	20M-2	20N-1	20N-2
				20L-3	20L-4	20M-3	20M-4	20N-3	20N-4
			21K-2	21L-1	21L-2	21M-1	21M-2		
			21K-4	21L-3	21L-4	21M-3			


5695
(716)
SAN SEWER
5GK-5695
6" VC
P2L5
P2L2
P2L3
P2L8
P2L4
P2L4SI
P2L1
MH
L114R12
L114R13
L114I4
L114R15L1
P-56
RAMP
3 2"S
10"
569
COOLING TOWER
ATKISSON ROAD

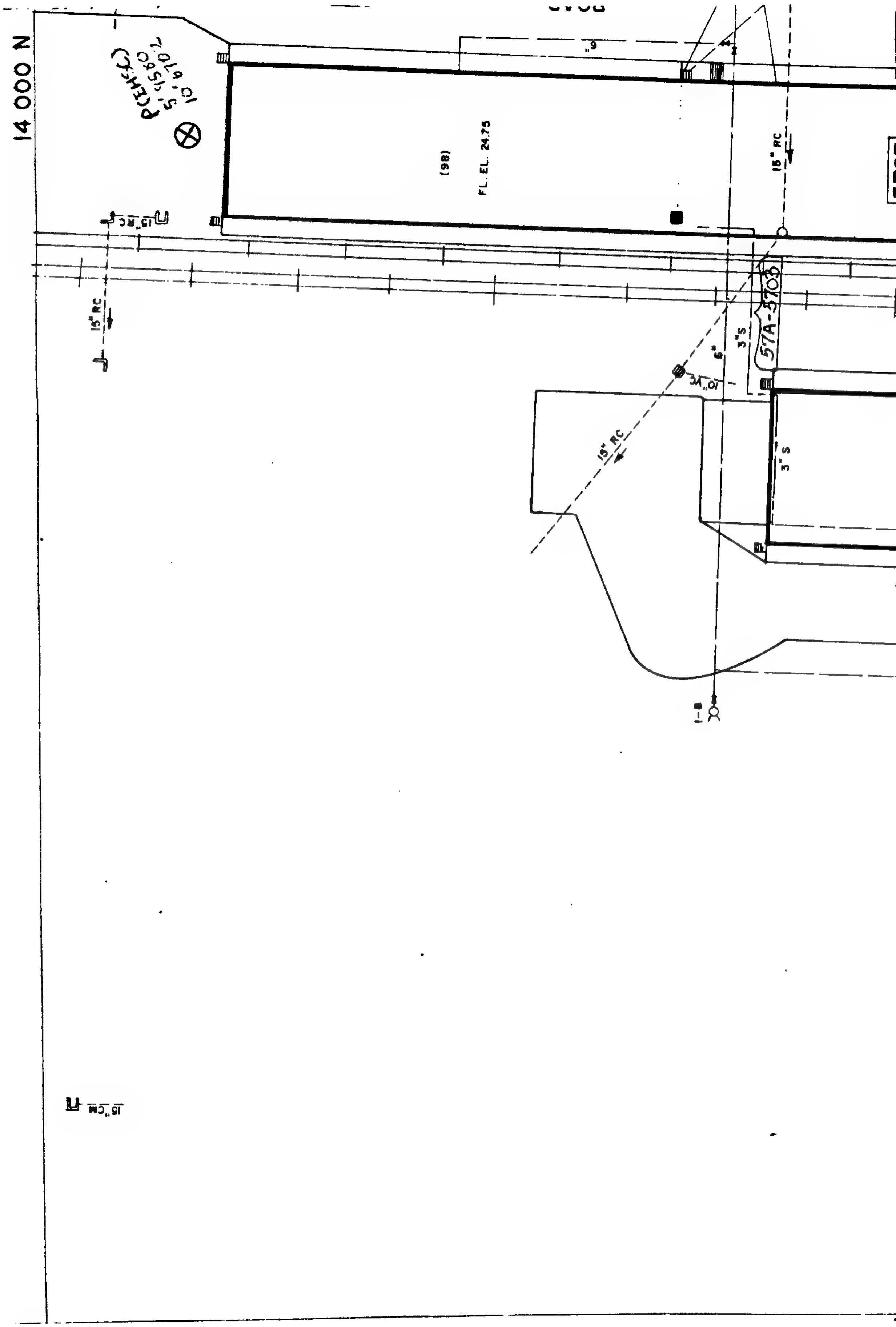
17J-3


STOKES
ROAD
5690
5691
(1716A)
5682
(T-713A)
P57-A
56FA-56K
56K
56K-5685
RAMP
CONC.
15" CONC
16" W
8" VC
P3
P5
P6
L29R3
L29R4

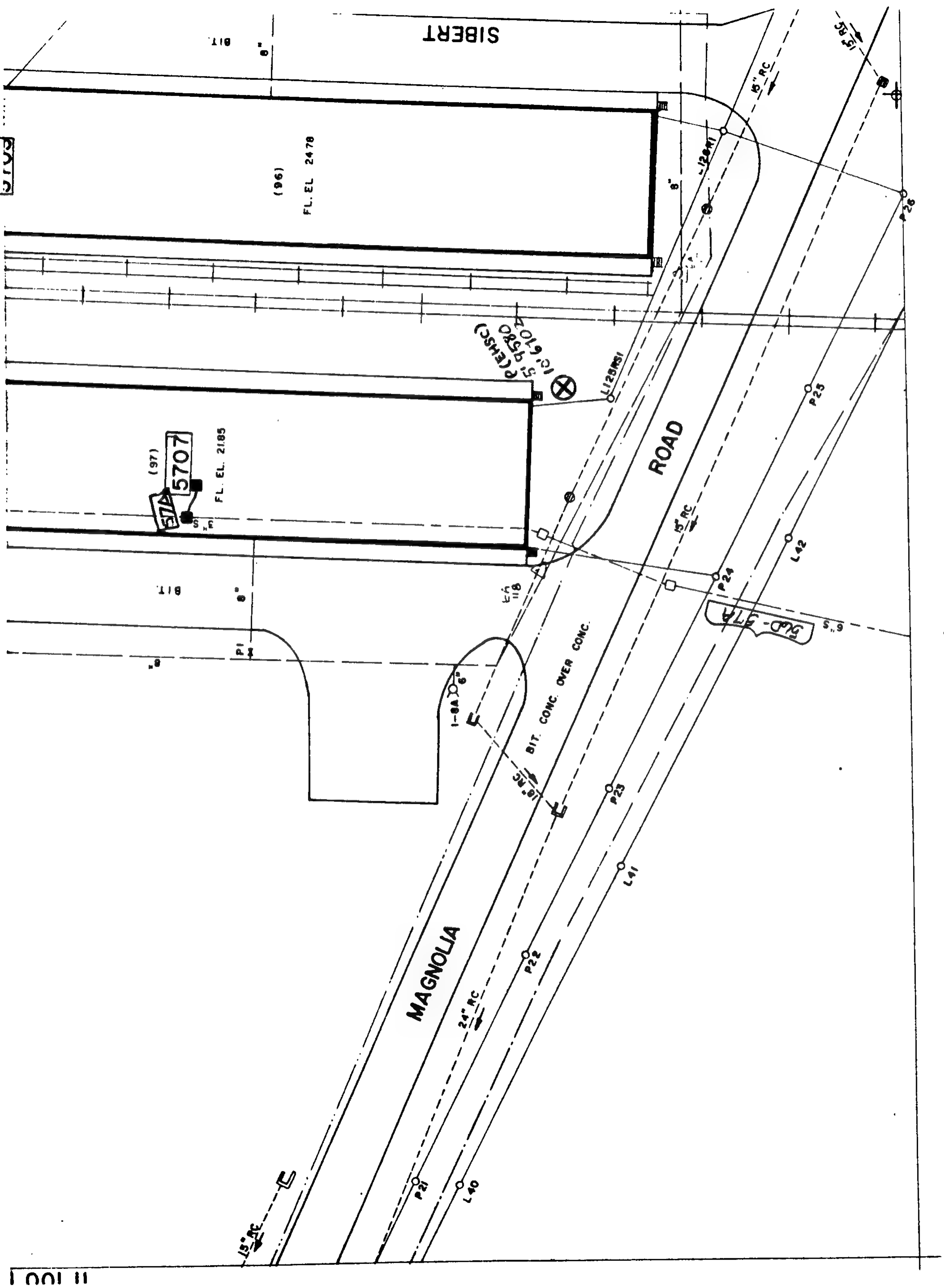
17J-4


ALLEY
ROAD
ROAD
GAS 3" STEEL
L12OL1
L12OL1SA
L12OL2
L12OLH
L12OLHI
L12OLH10
L12OLH84
L12OLH9
L12OL2RS1
P20
P19
P18
L39
L38
I-45
P 59
5648
FL EL 11 58
5643
15" RC
24" RC
18" RC
6" VC
6" TC
2" S
1-1/2"
8"
4"
3"

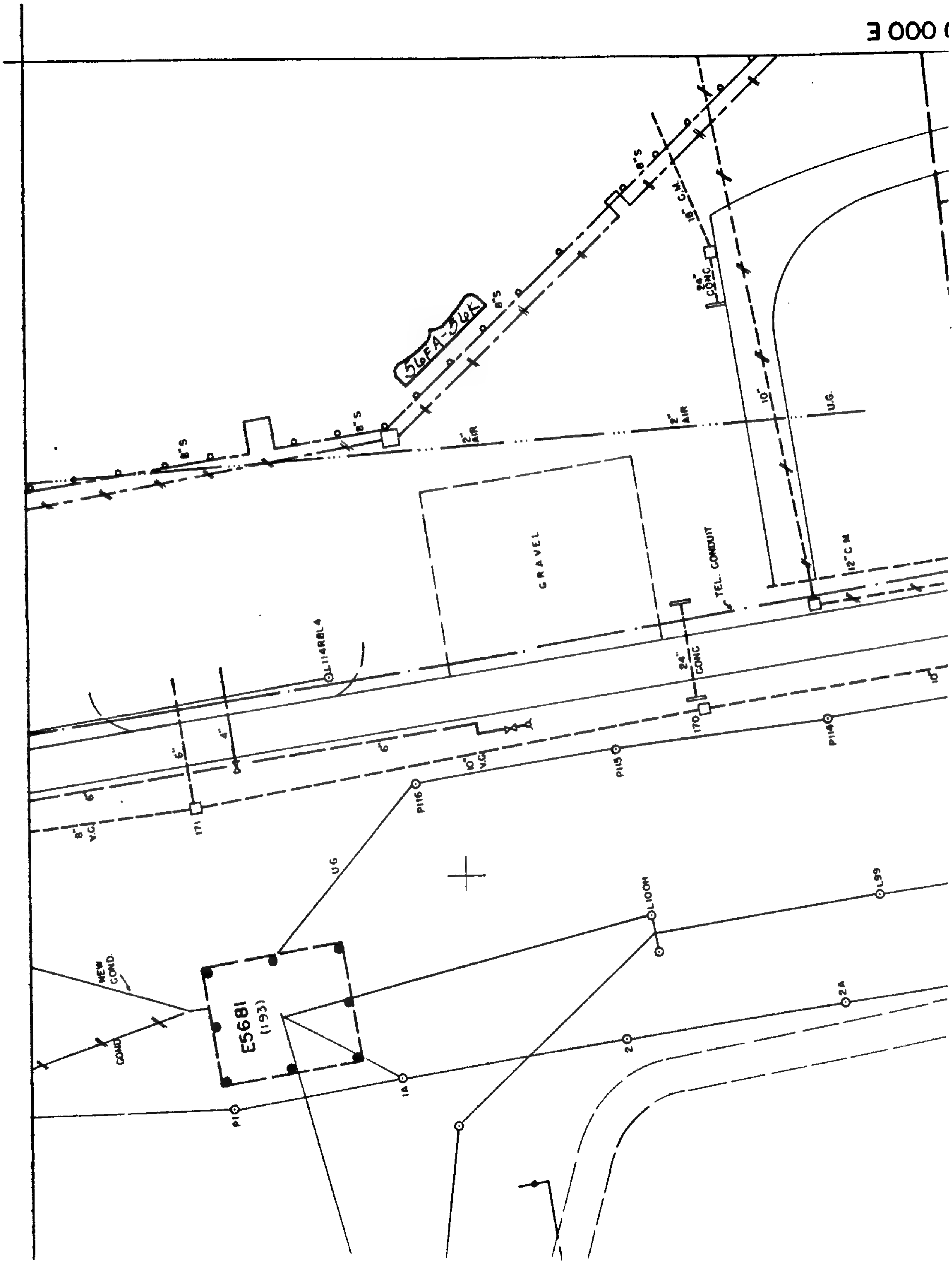
17K-4



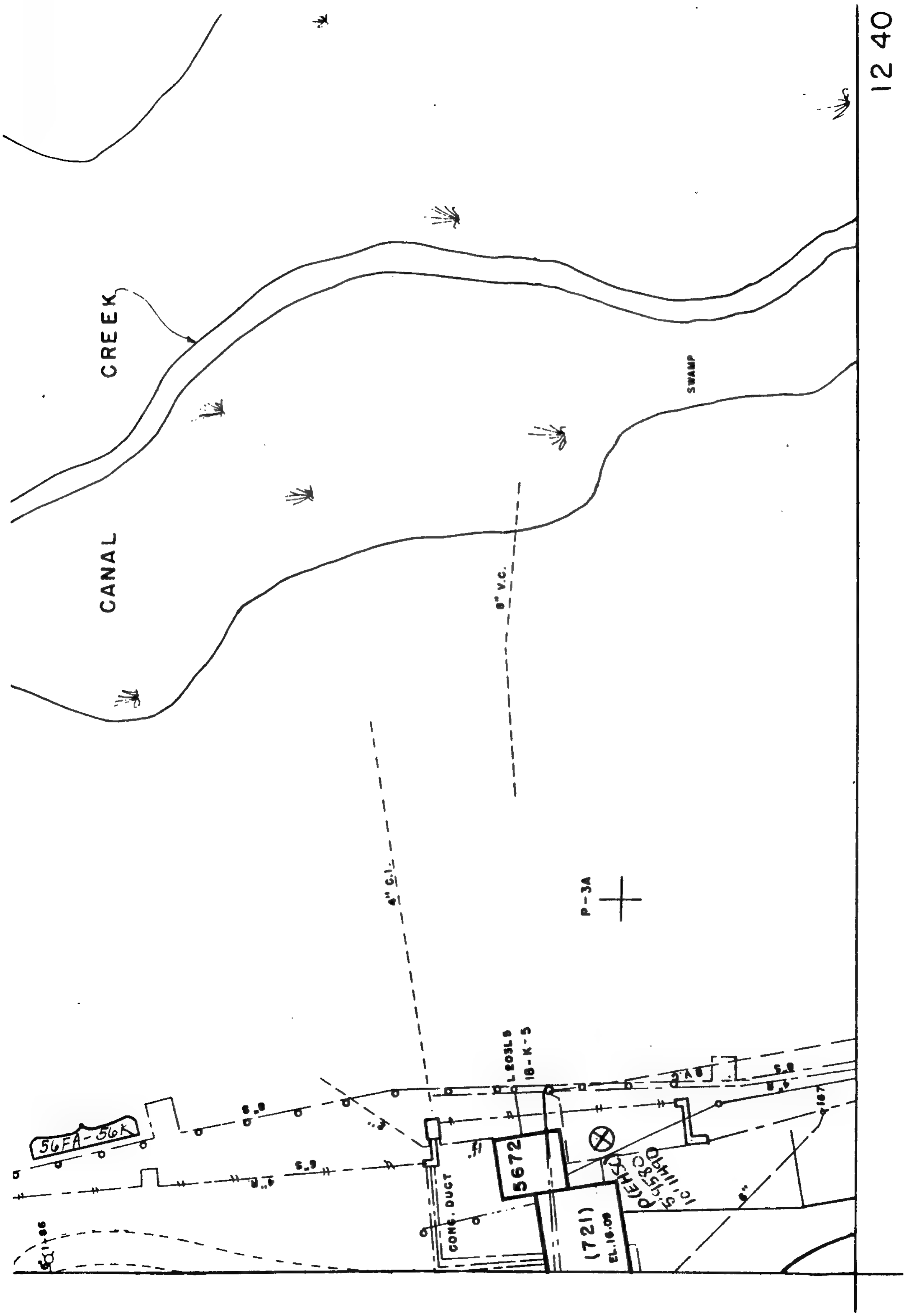
17L-1


SIBERT
ROAD
MAGNOLIA
5707
FL. EL. 2478
FL. EL. 21.85
BIT. CONC. OVER CONC.
15" RC
24" RC
P21
P22
P23
P24
P25
P26
L40
L41
L42

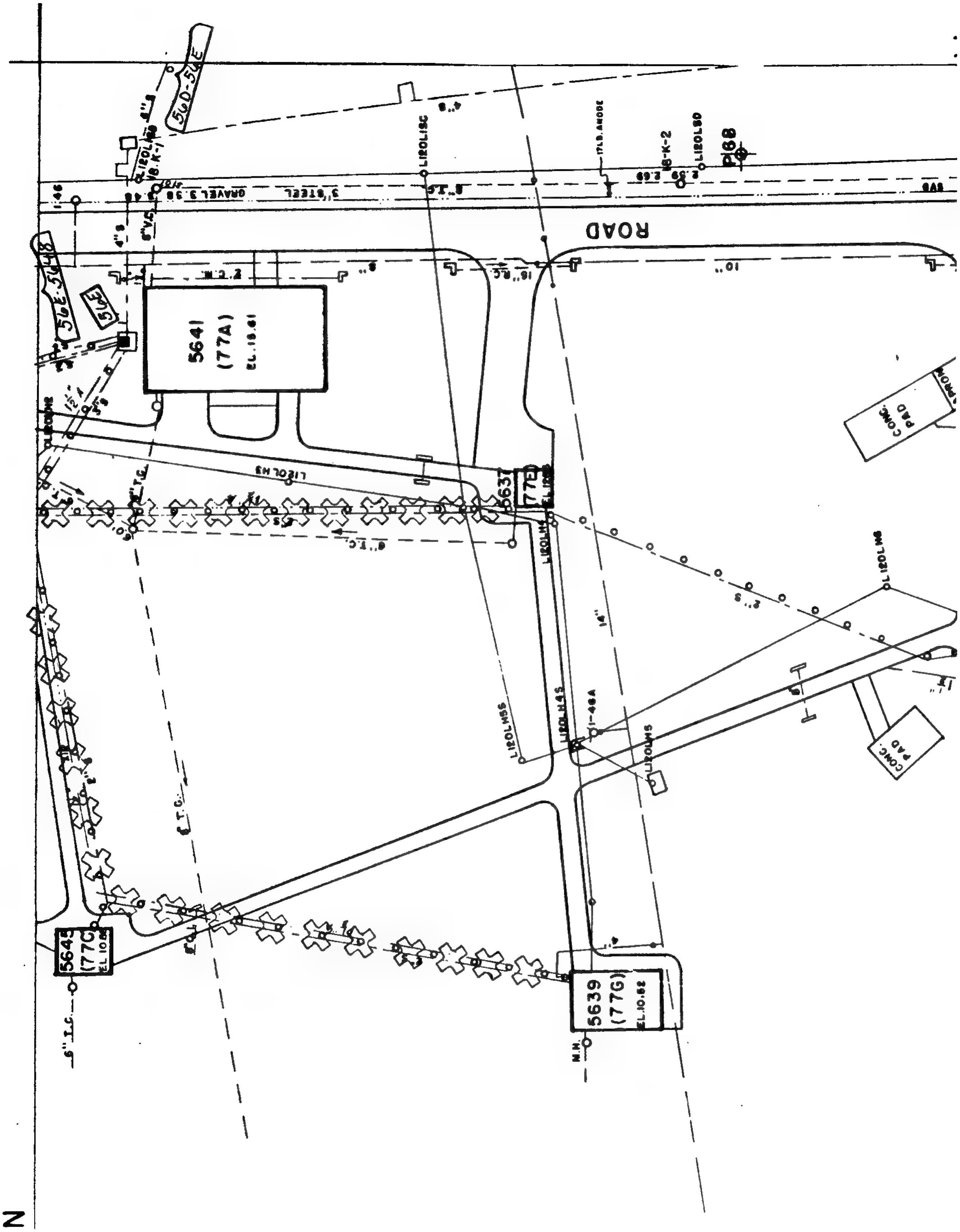
17L-3


3 000 E
GRAVEL
TEL. CONDUIT
24" CONC
18" C.M.
12" C M
8"S
2" AIR
U.G.
56FA-56K
E5681
(193)
P116
P115
P114
171
170
L100M
L99
2A
2
1A
P1
NEW COND.
COND
UG
8" V.C.

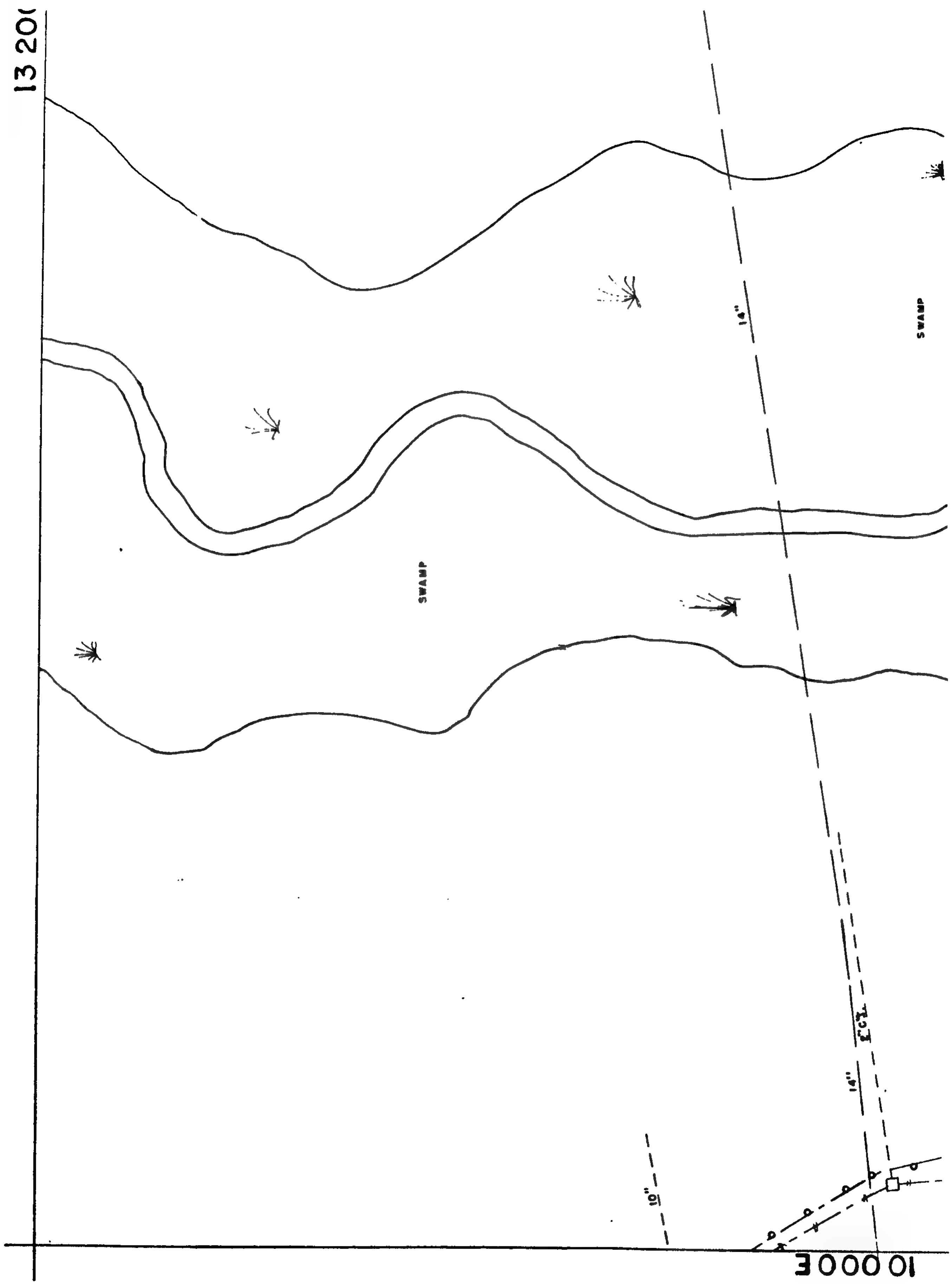
18J-2

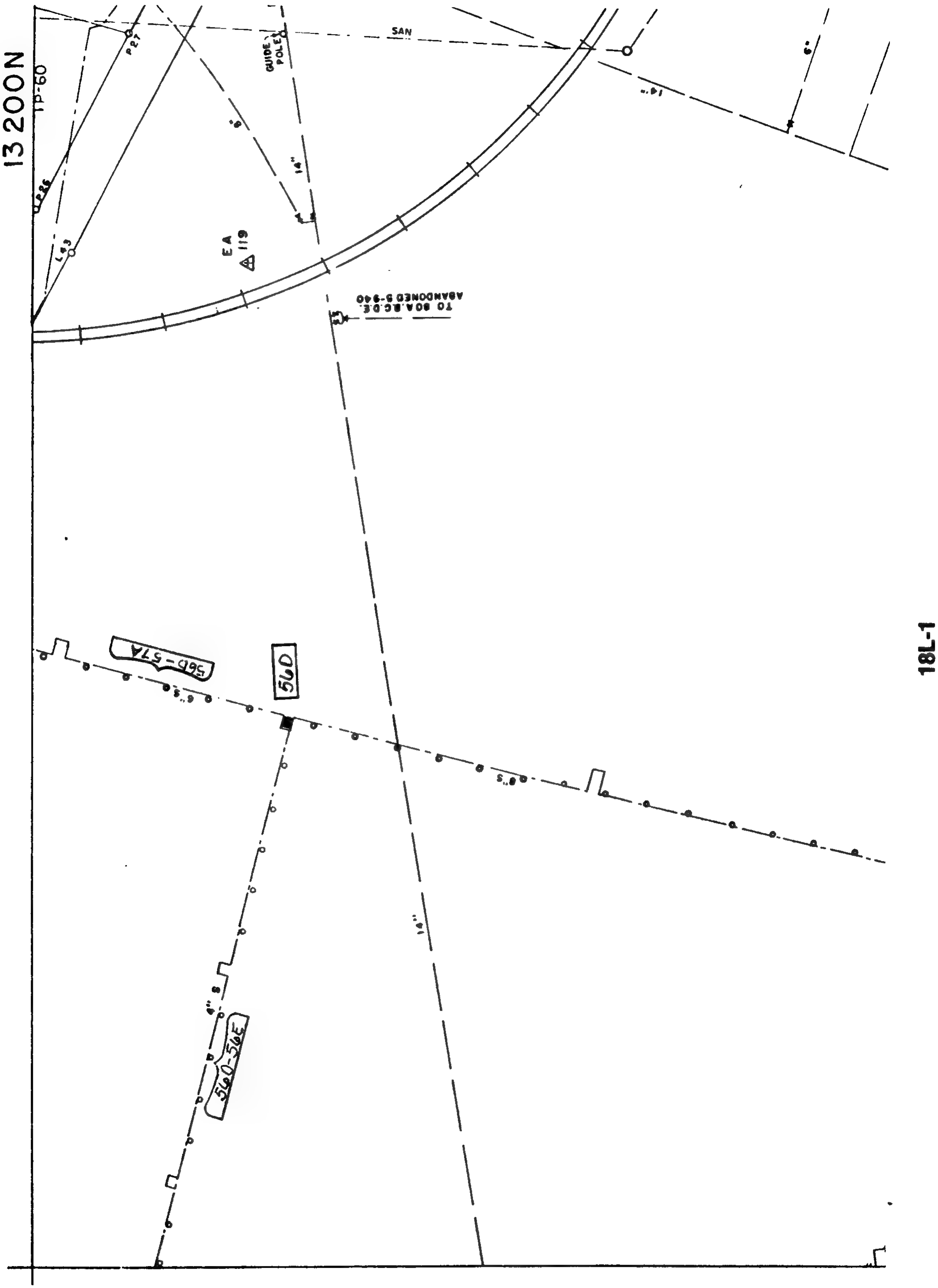

12 40
CREEK
CANAL
SWAMP
8" V.C.
4" C.I.
P-3A
5672
(721)
CONC. DUCT
56FA-56K

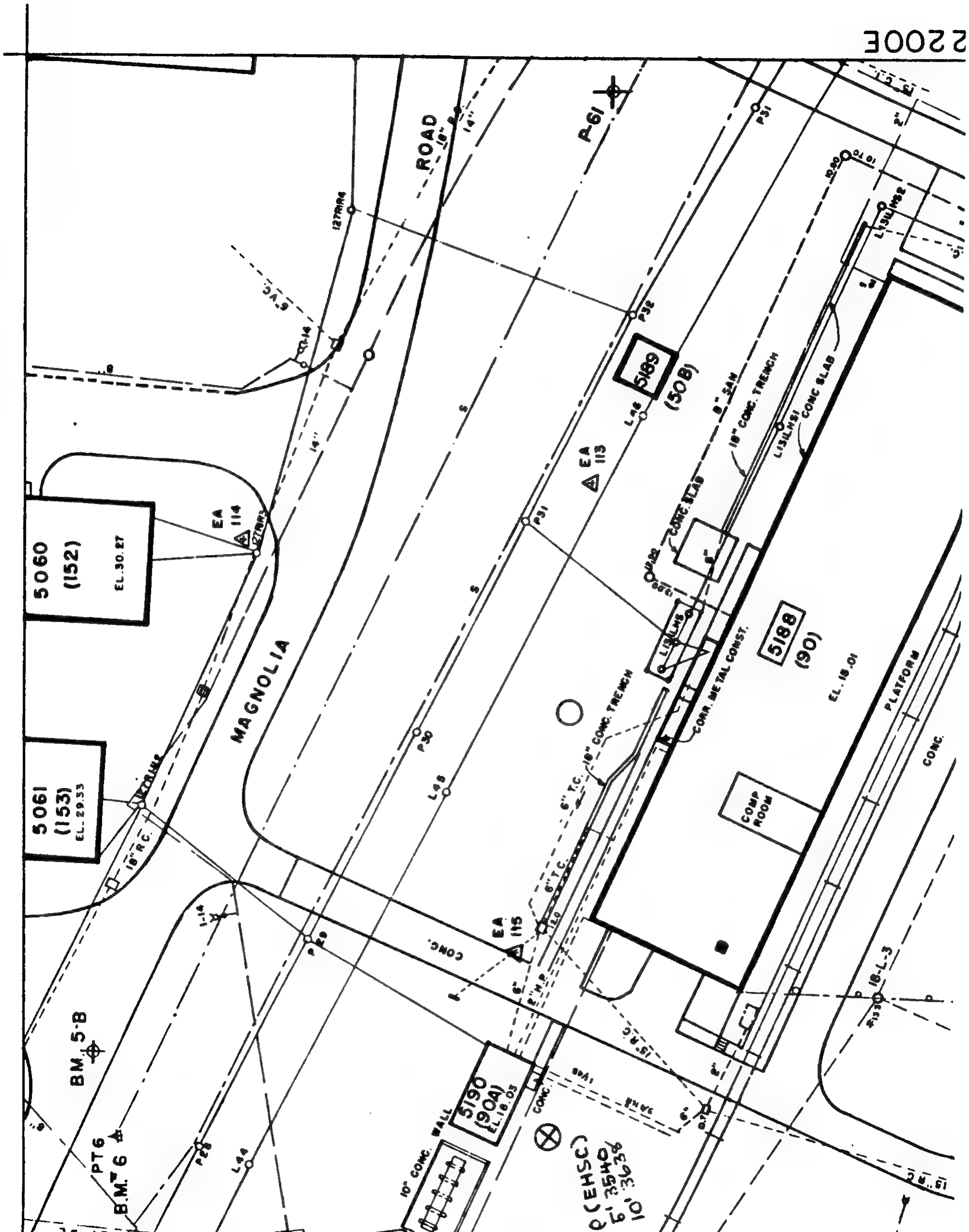
18K-1



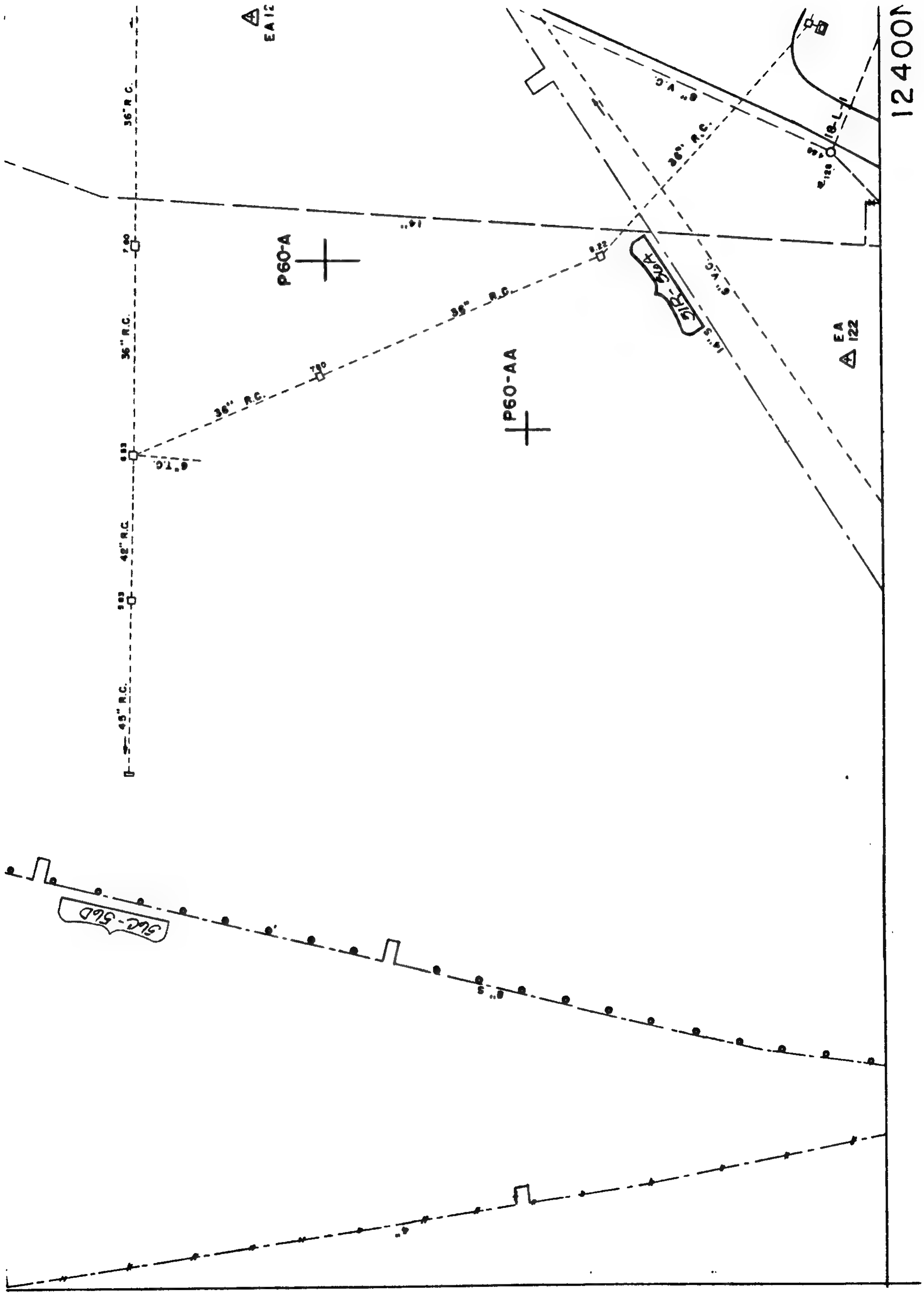
18K-2


13 20
SWAMP
14"
SWAMP
18K-3
14"
10"
10 000 E

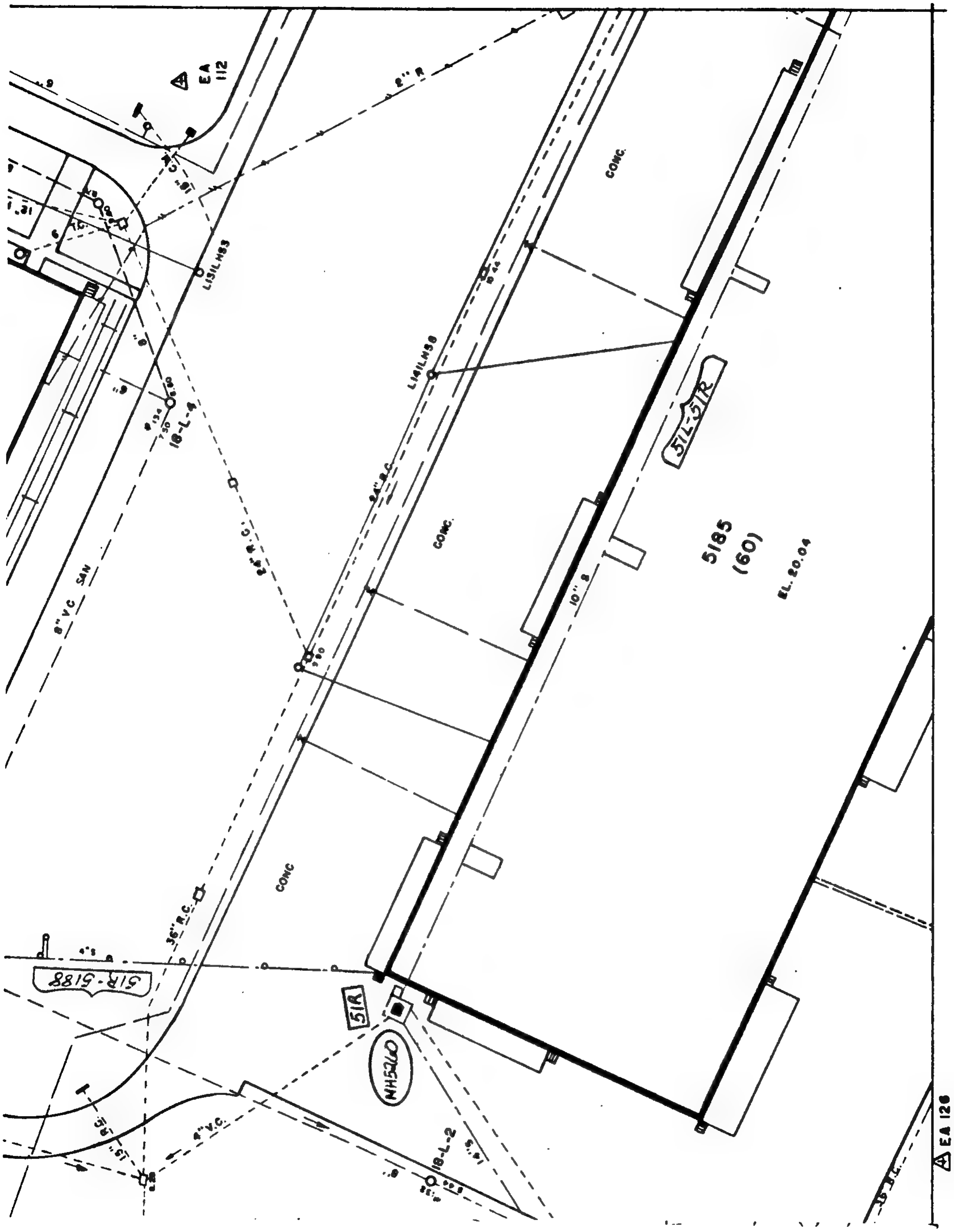

13200N
TP-60
SAN
GUIDE POLE
P27
P26
L43
EA 119
14"
6"
56D-57A
56D
8" S
4" S
56D-56E
18L-1


2200E
MAGNOLIA
ROAD
5060
(152)
EL. 30.27
5061
(153)
EL. 29.33
5188
(90)
EL. 18.01
5189
(50B)
5190
(90A)
EL. 18.03
PLATFORM
COMP ROOM
CORR. METAL CONST.
CONC. SLAB
18" CONC. TRENCH
10" CONC. WALL
BM. 5-B
PT 6
EA 113
EA 114
EA 115
P-61
18-L-3

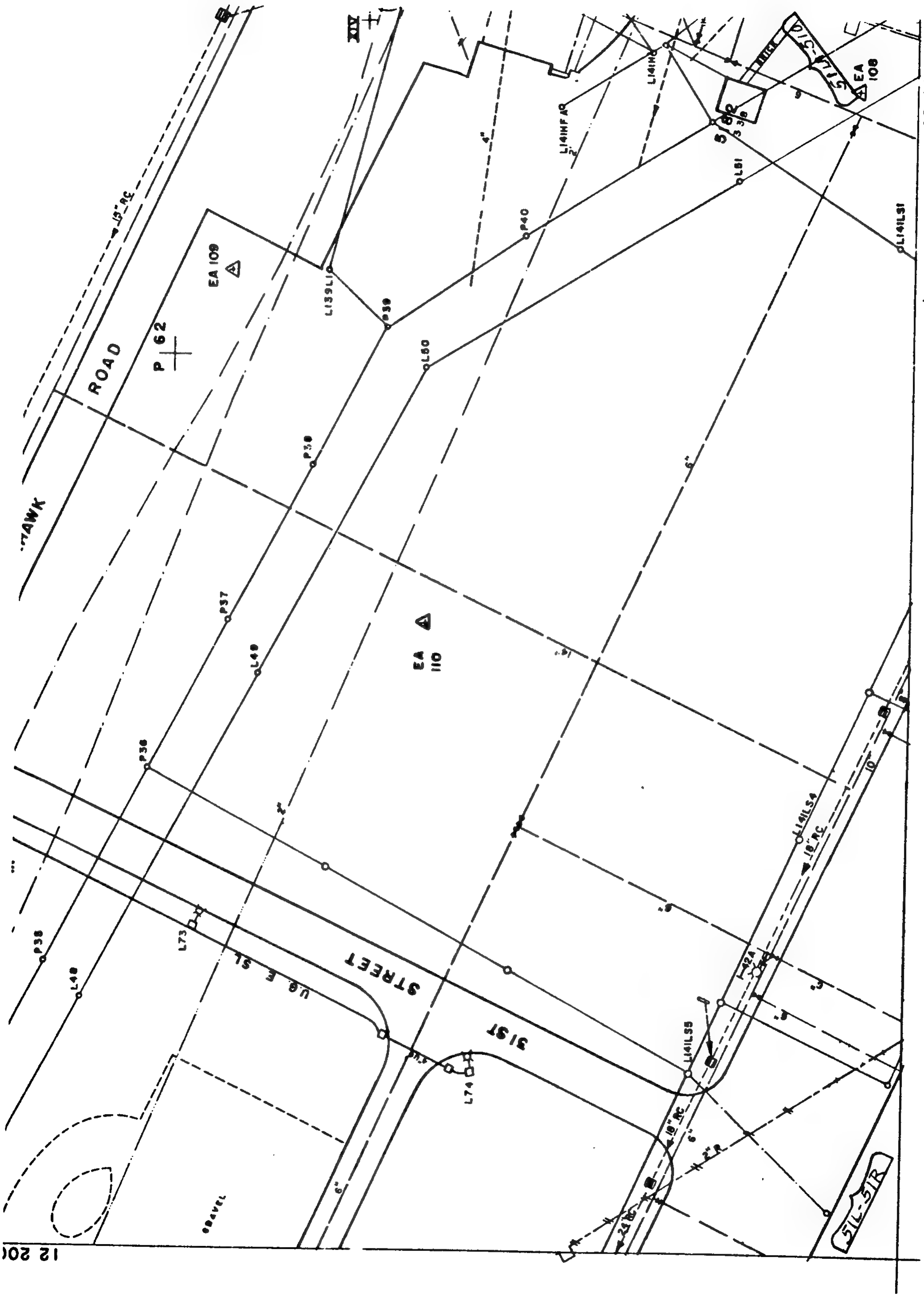
18L-2



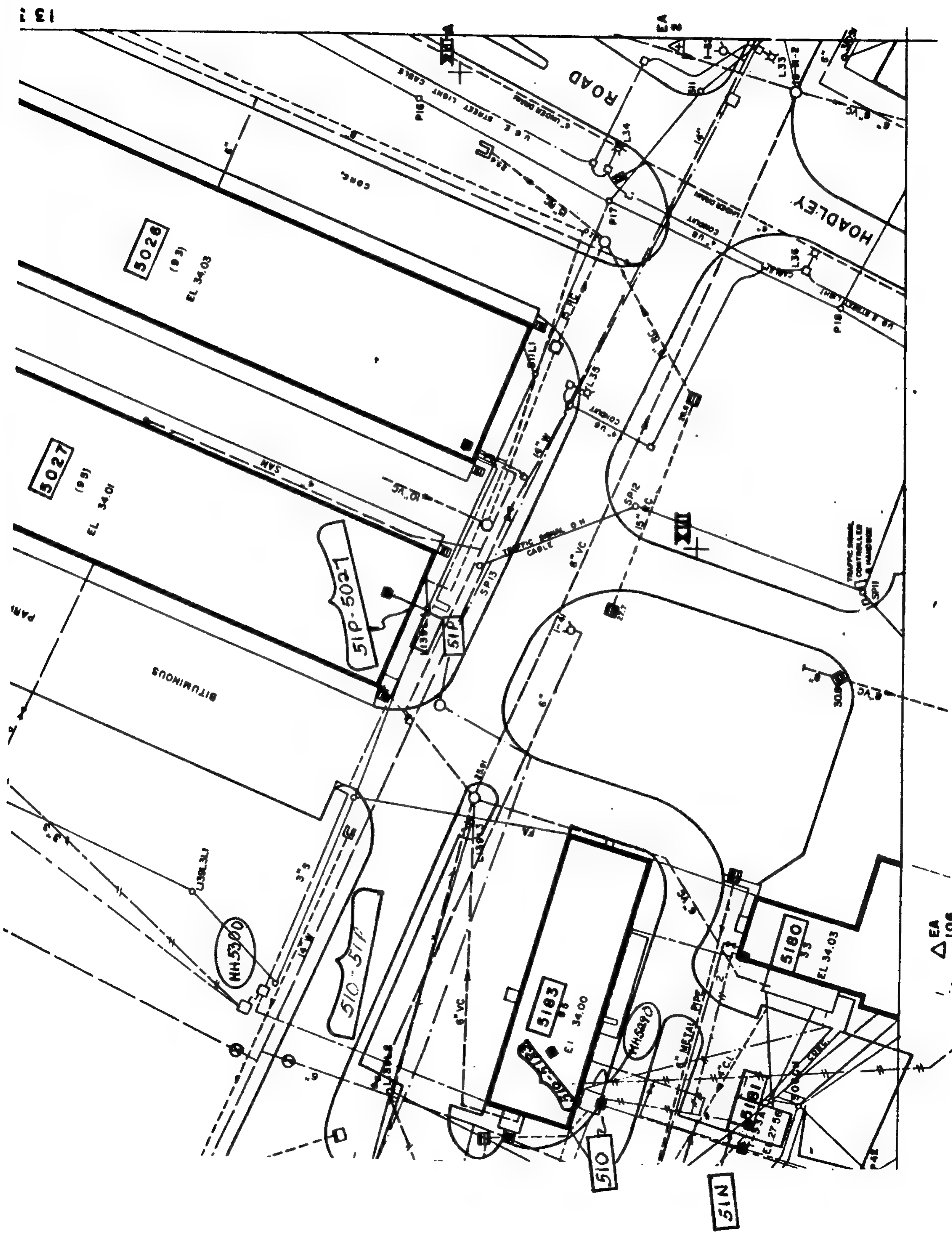
18L-3


5185
(60)
EL. 20.04
CONC.
CONC.
CONC
51L-51R
51R-5188
51R
18-L-4
18-L-2
EA 112
EA 126
8" V.C. SAN
24" R.C.
36" R.C.
10" S

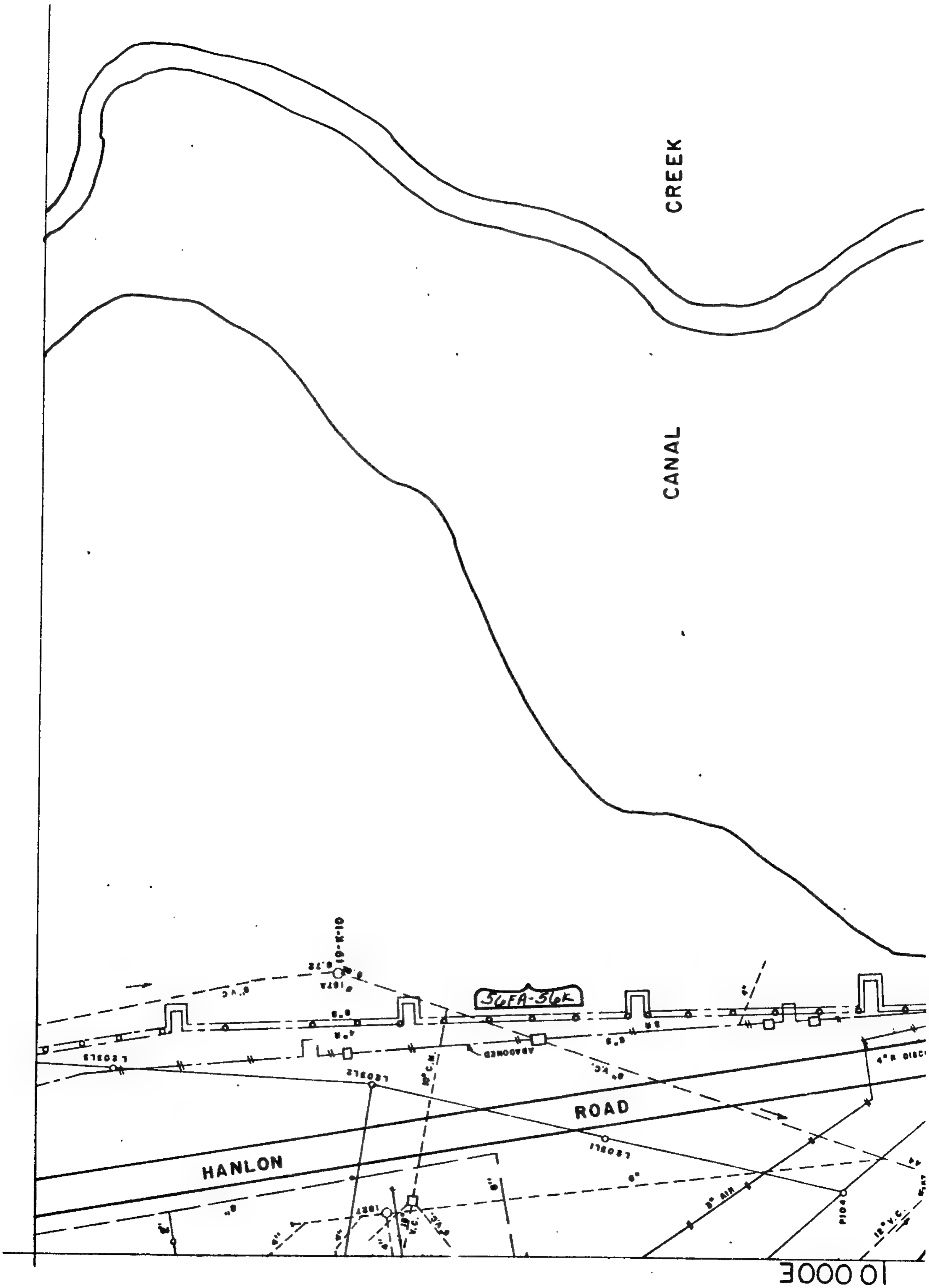
18L-4


ROAD
P 62
EA 109
EA 110
EA 108
STREET
31ST
12 400 N
P36
P37
P38
P39
P40
L48
L49
L50
L51
L73
L74
L139L1
L141L54
L141L55
L141L51
18" RC
GRAVEL

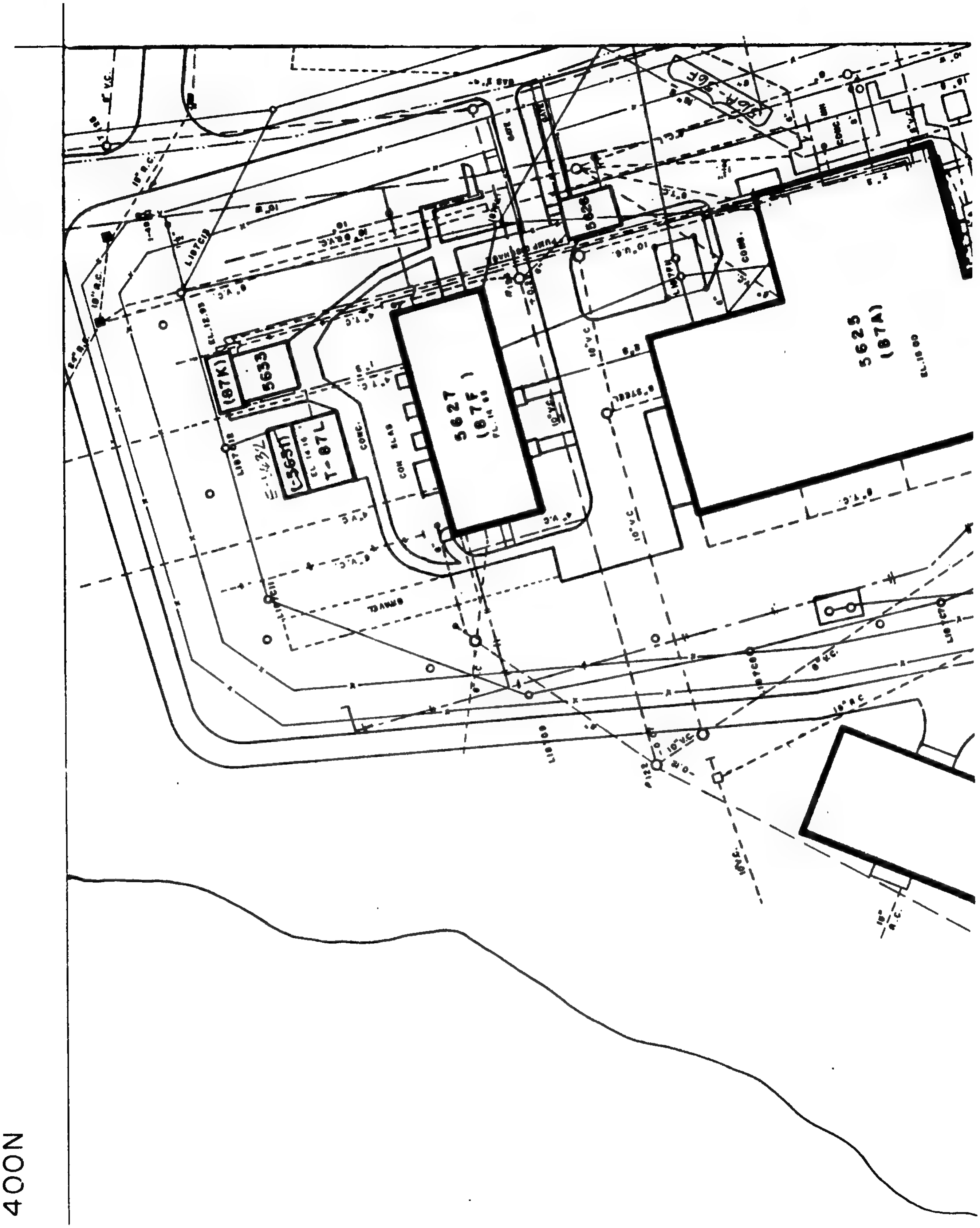
18M-3


HOADLEY
ROAD
5026
EL 34.03
5027
EL 34.01
BITUMINOUS
51P-5027
5183
5180
EL 34.03
MH5300
MH5290
510
51N
TRAFFIC SIGNAL CABLE
6" METAL PIPE

18M-4

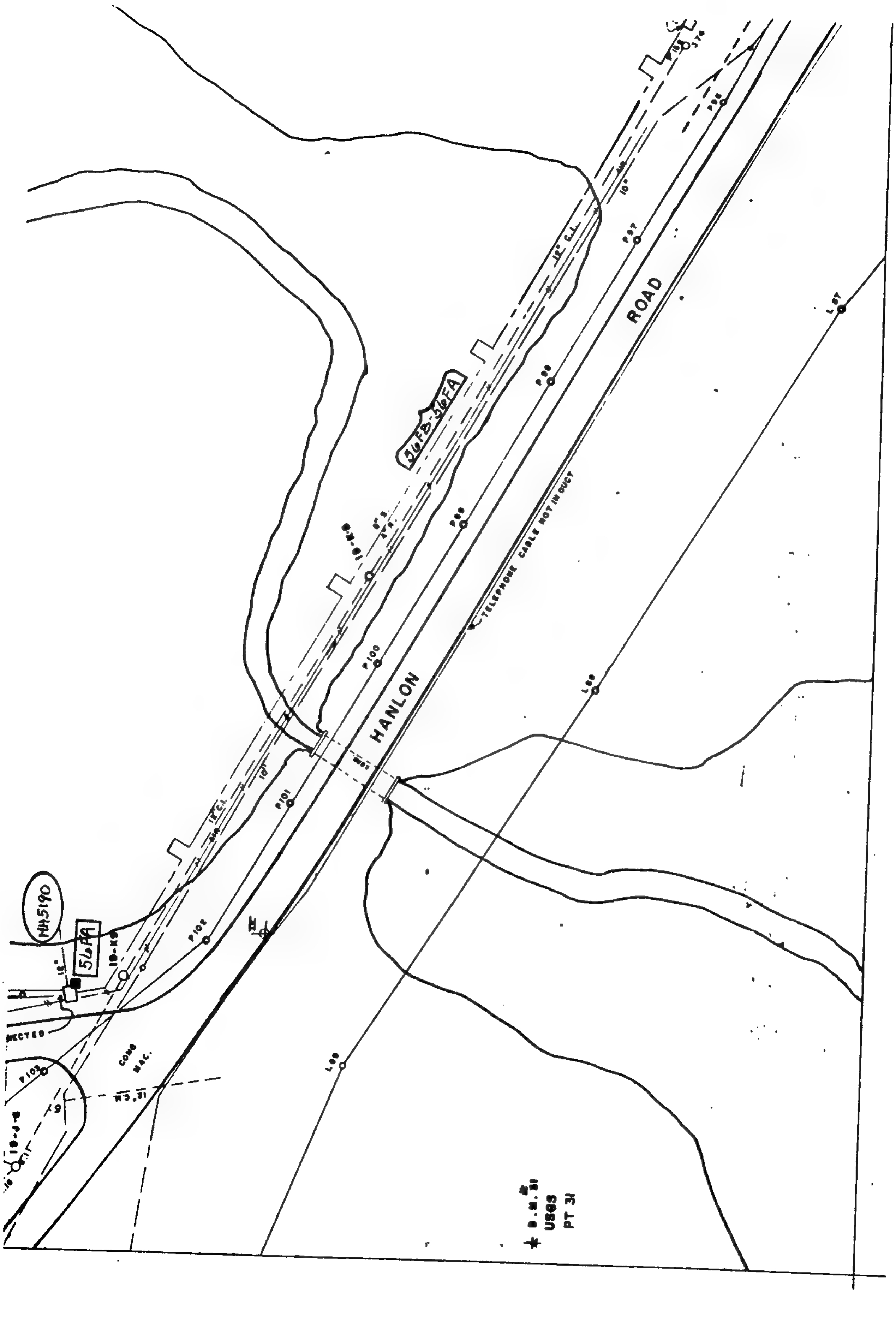


19K-1

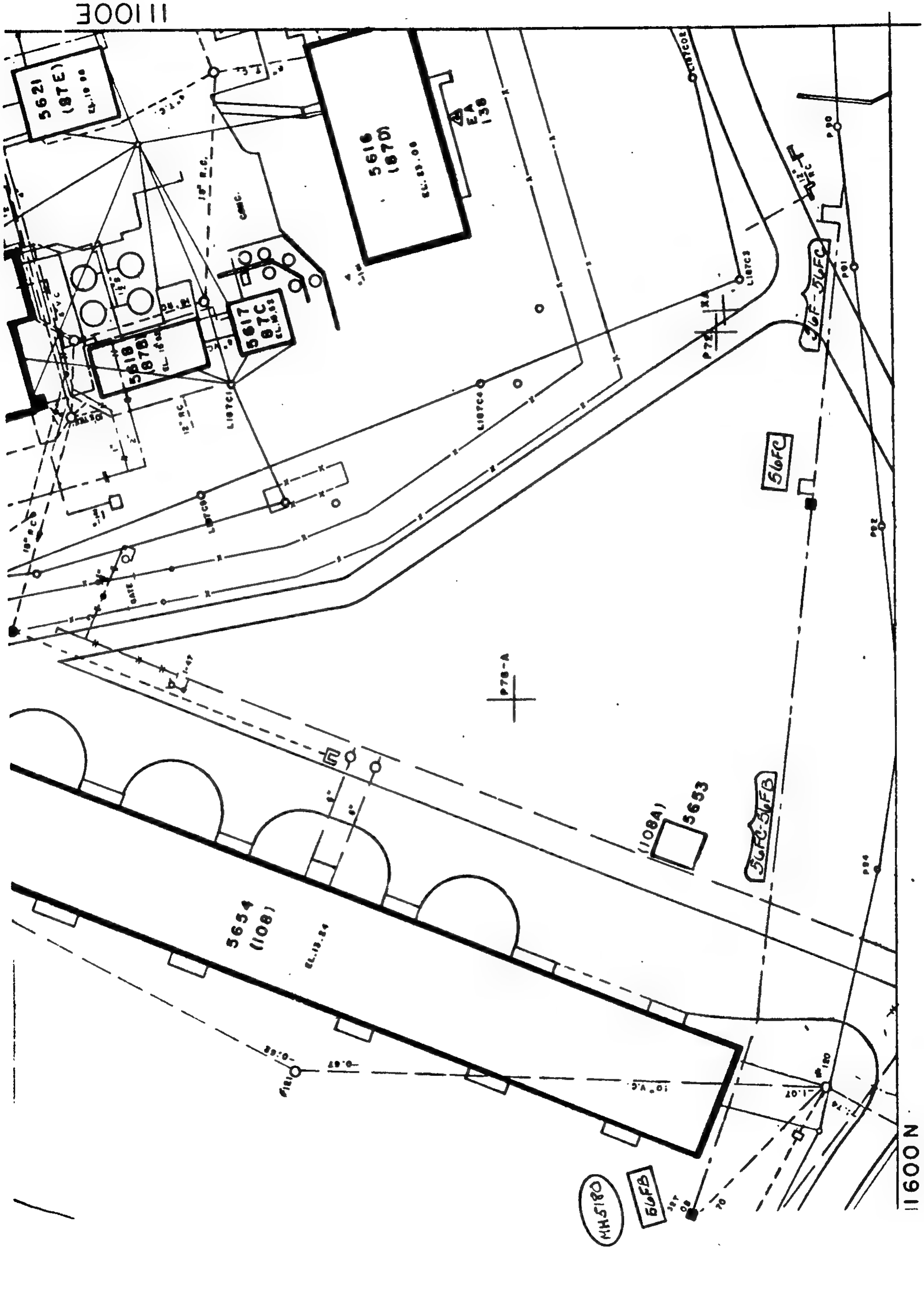


19K-2

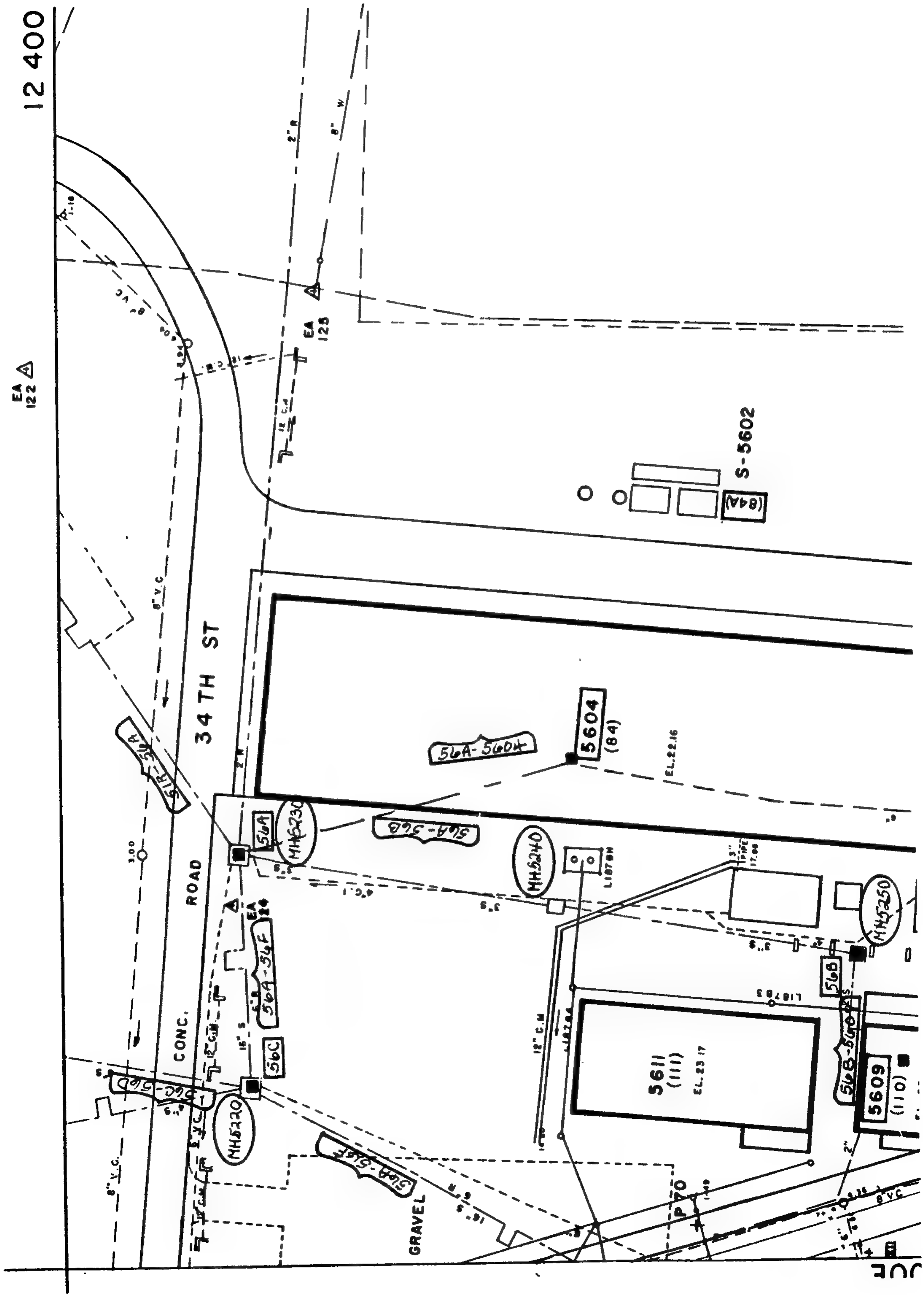
400N

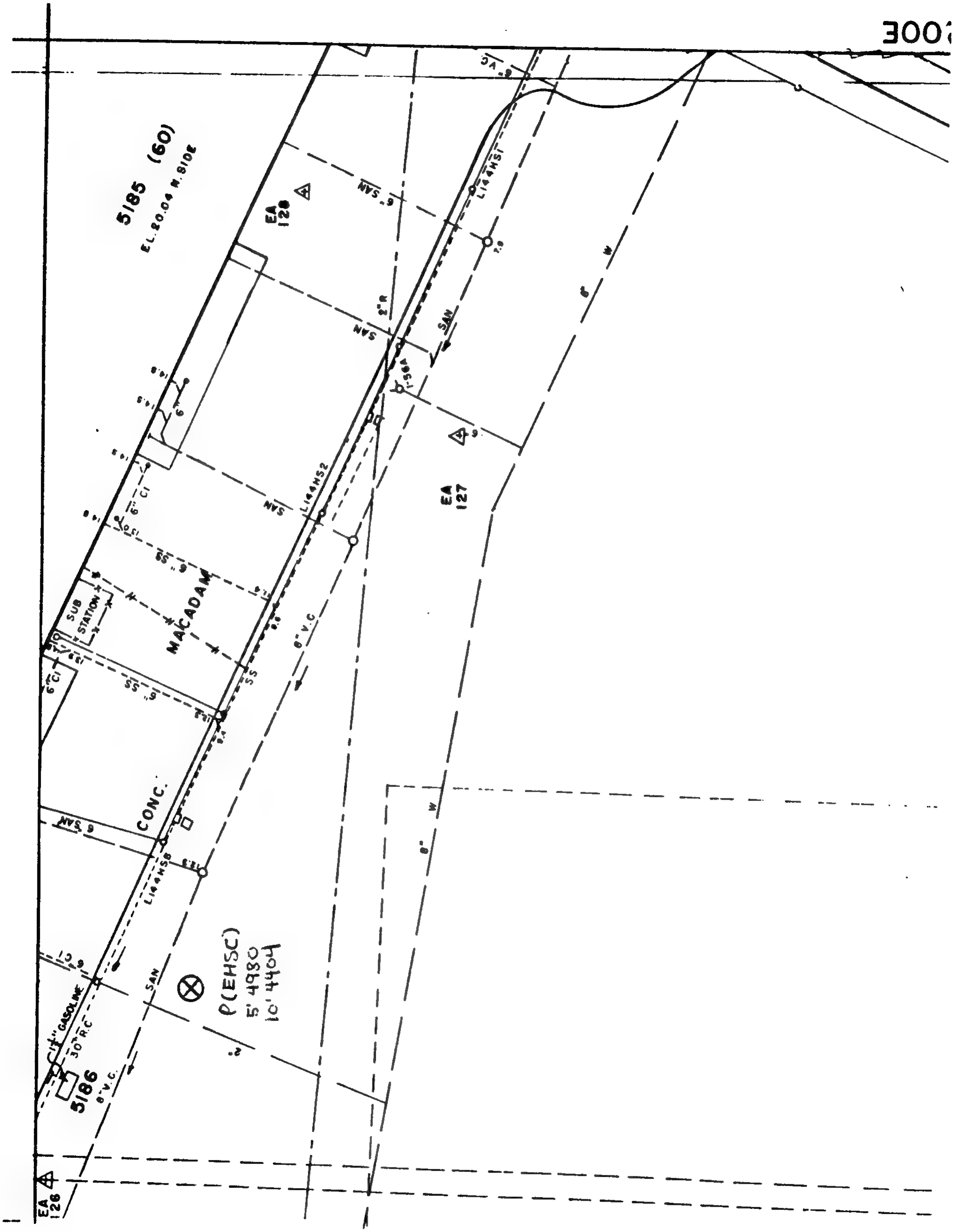

HANLON
ROAD
TELEPHONE CABLE NOT IN DUCT
56FB-56FA
MH5190
56FA
CONC
MAC.
B.M. 31
USGS
PT 31

19K-3

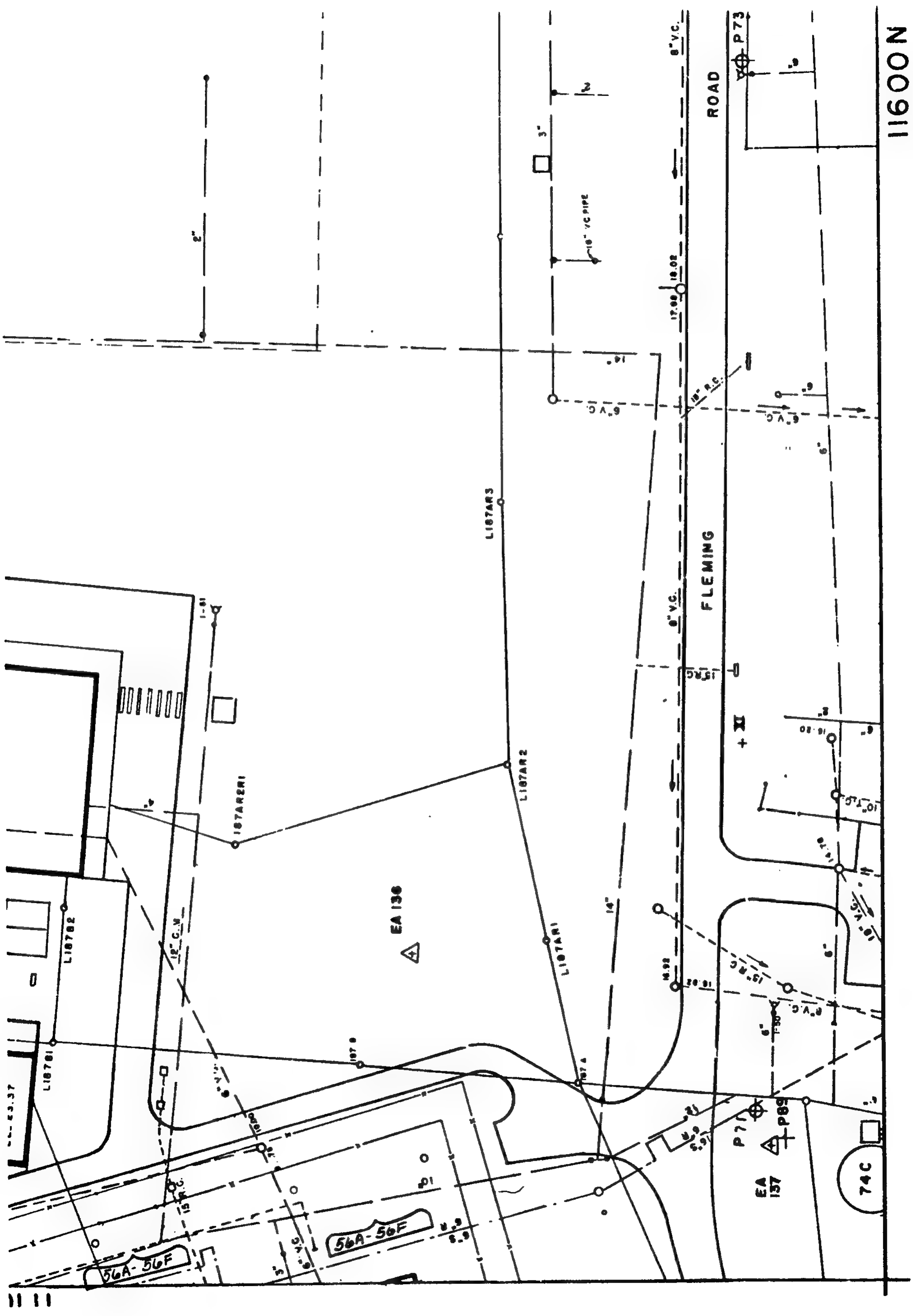

11100E
5621
(87E)
5616
(87D)
EA
138
5617
87C
5618
(87B)
56FC
56F-56FC
5653
(108A)
56FC-56FB
5654
(108)
56FB
MH5180
1600 N

19K-4

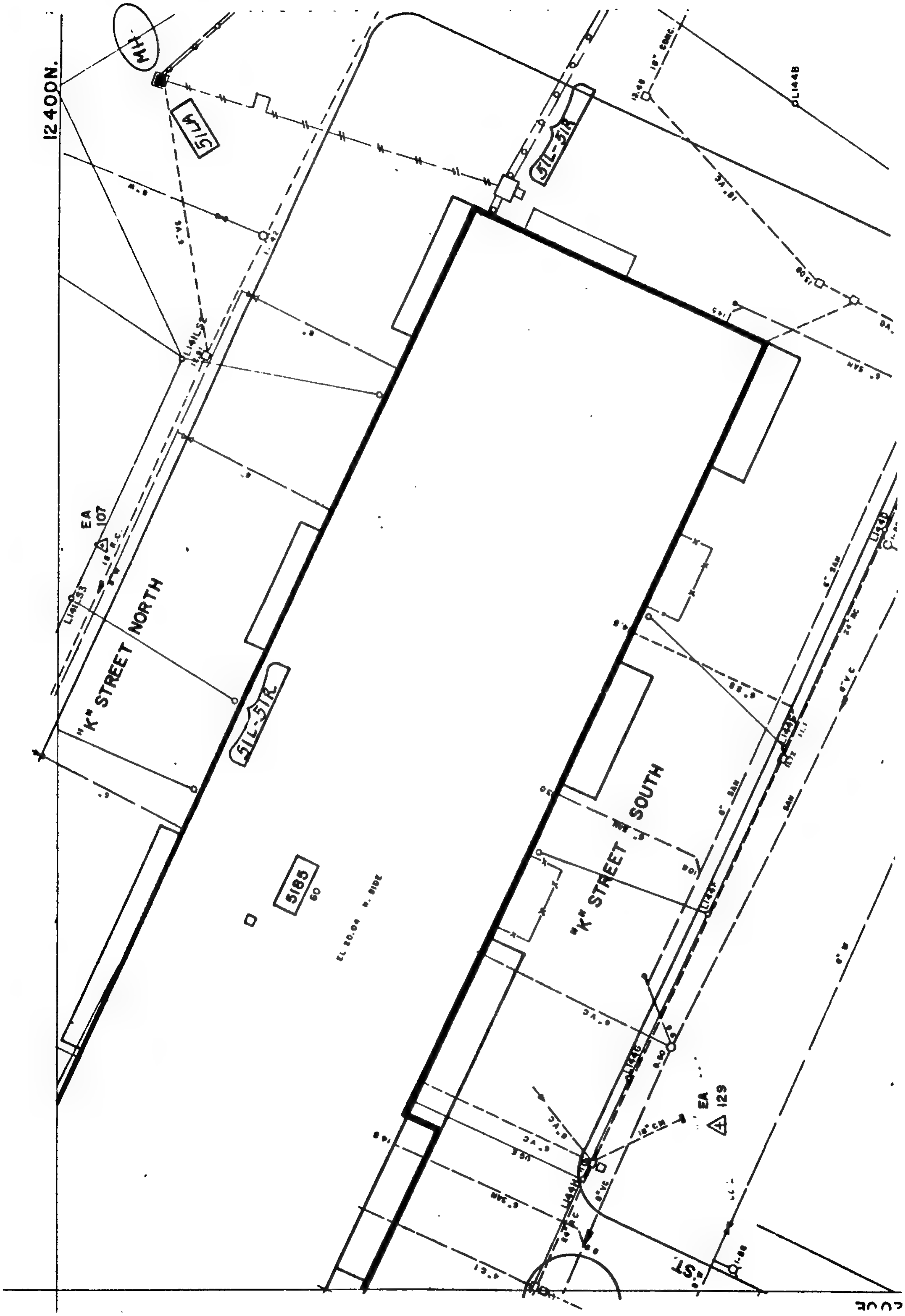

12 400
34 TH ST
ROAD
CONC.
GRAVEL
S-5602
5604
(84)
5611
(111)
5609
(110)
MH5220
MH5230
MH5240
MH5250
19L-1


5185 (60)
EA 128
EA 127
EA 126
MACADAM
CONC.
SUB STATION
5186
P(EHSC)
5' 4980
10' 4404

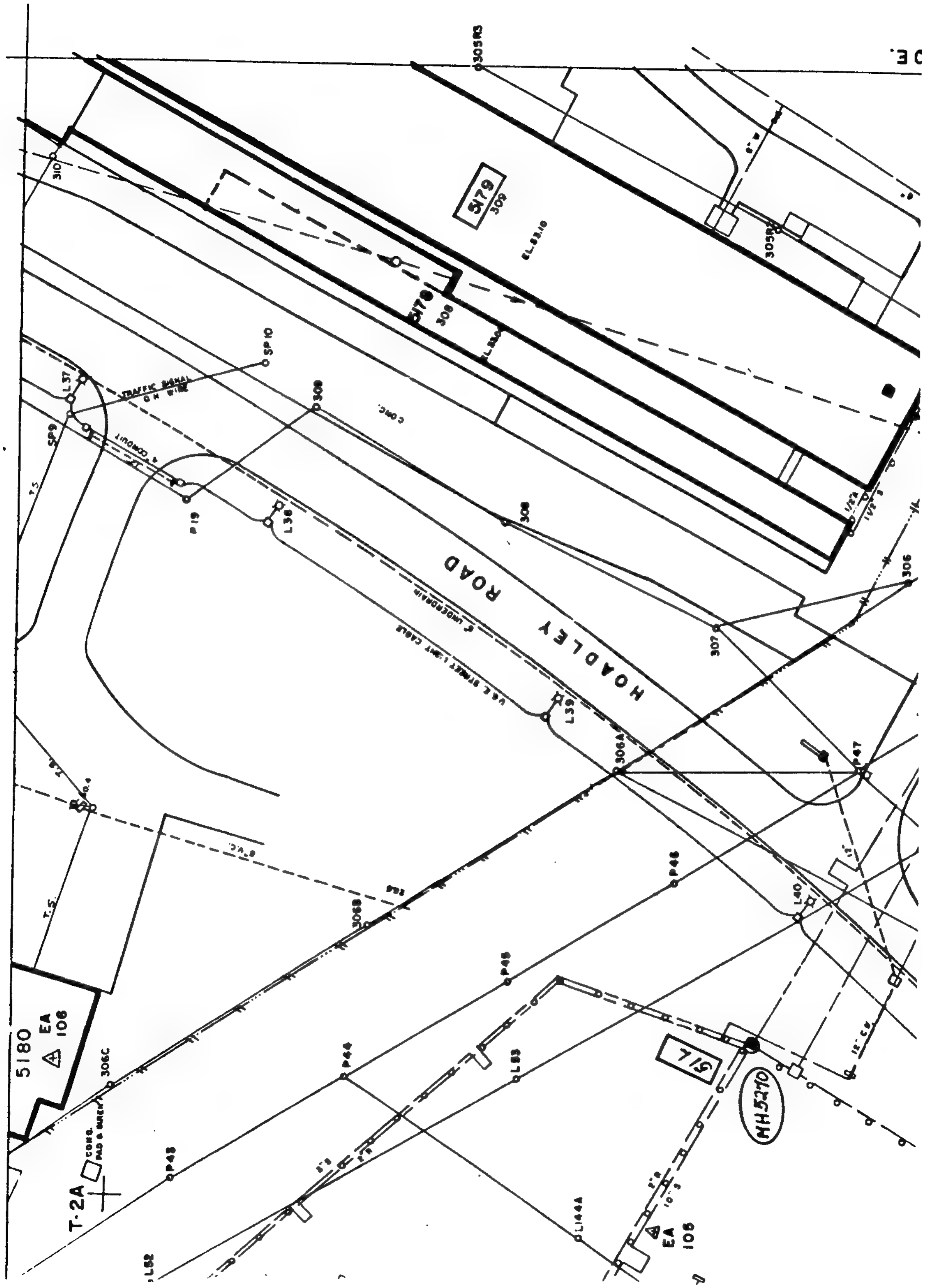
19L-2


FLEMING
ROAD
11600 N
EA 136
EA 137
74C
56A-56F
56A-56F
P73
P89
L187AR1
L187AR2
L187AR3
L187B1
L187B2
187AR2R1
16" VC PIPE

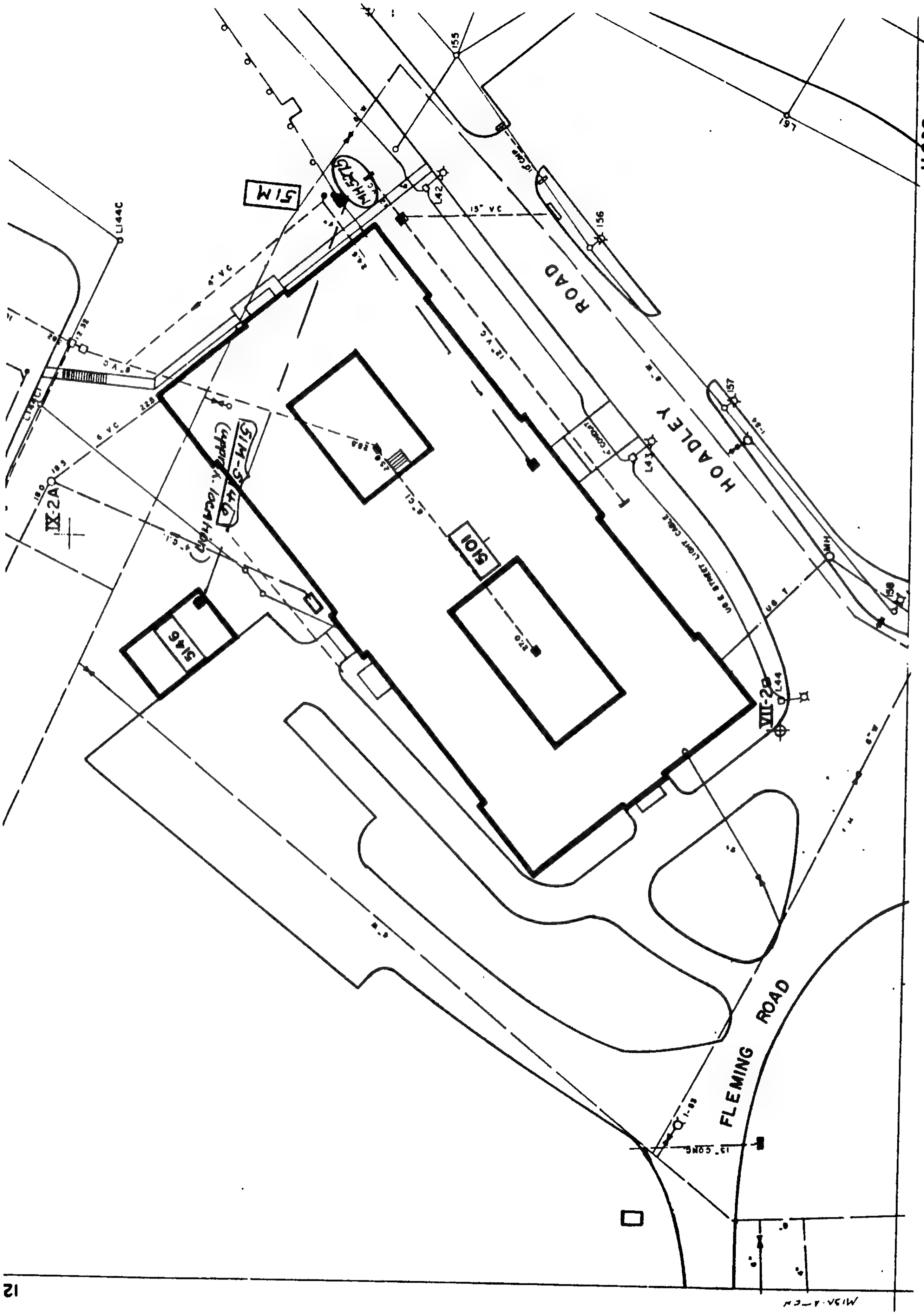
19L-3


12400N.
MH
51LA
51L-51R
EA 107
"K" STREET NORTH
5185
"K" STREET SOUTH
EA 129
L1448

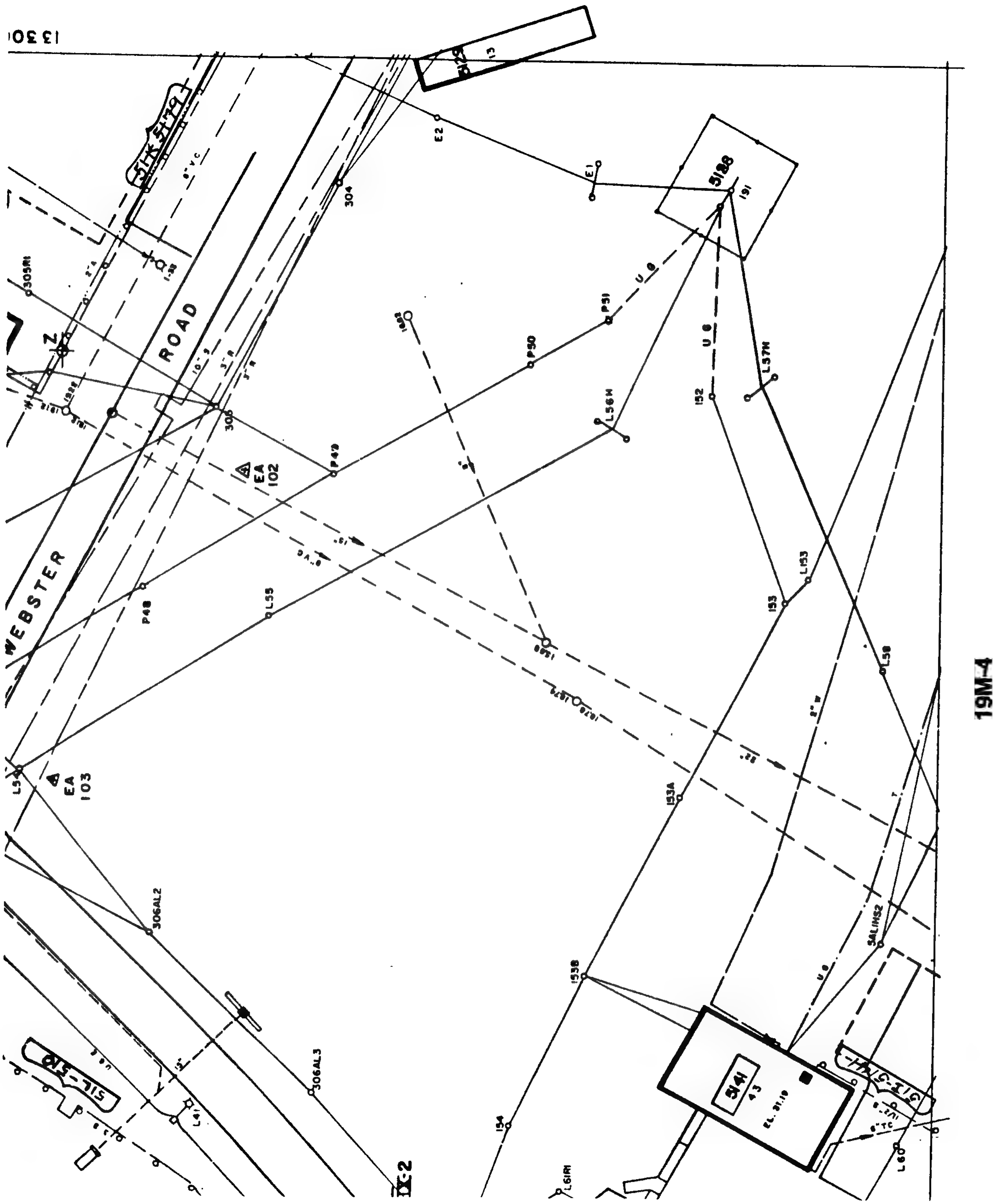
19M-1

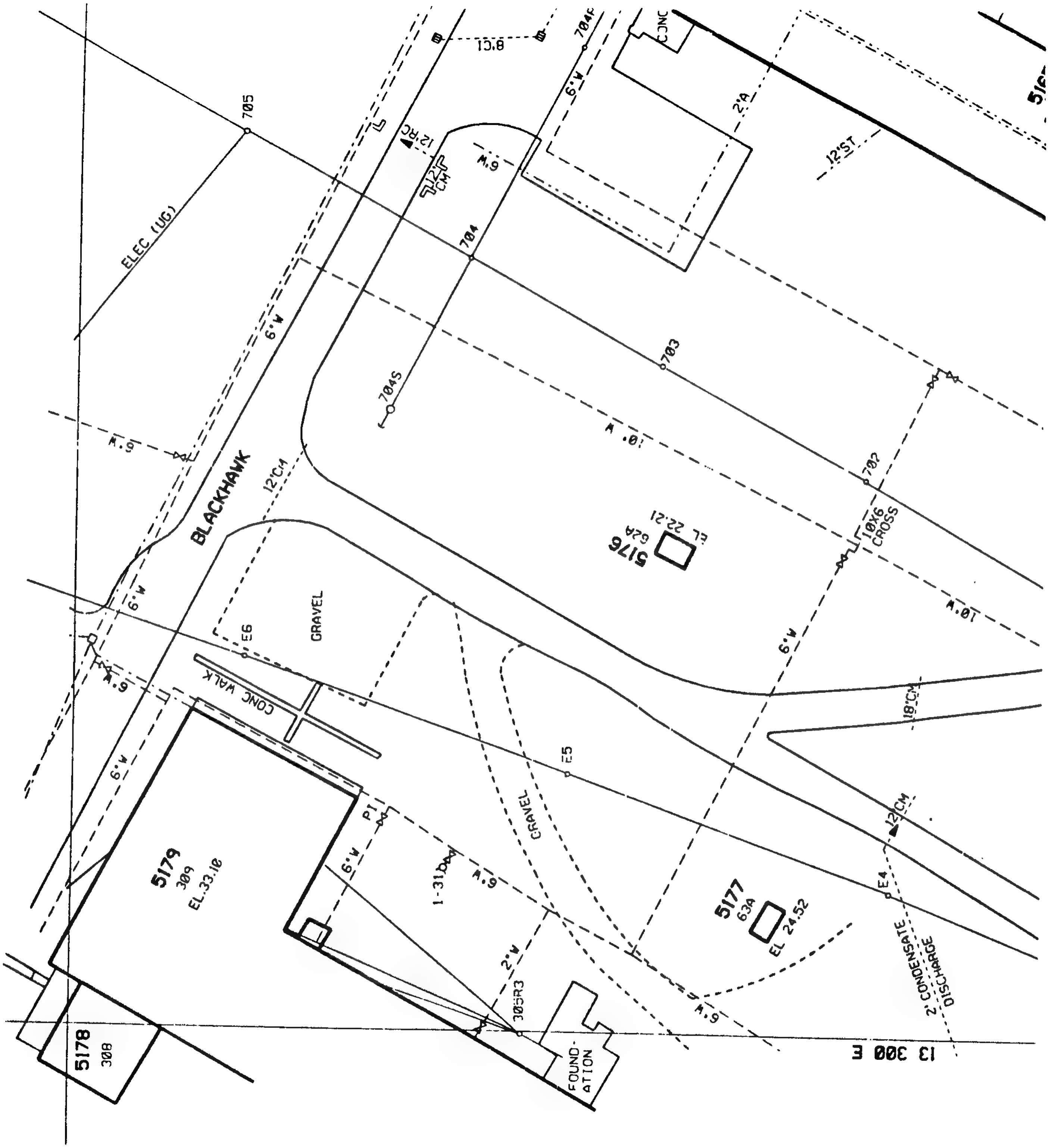

HOADLEY ROAD
5179
309
5180
EA 106
T-2A
6" UNDERDRAIN
TRAFFIC SIGNAL O.H. WIRE

19M-2

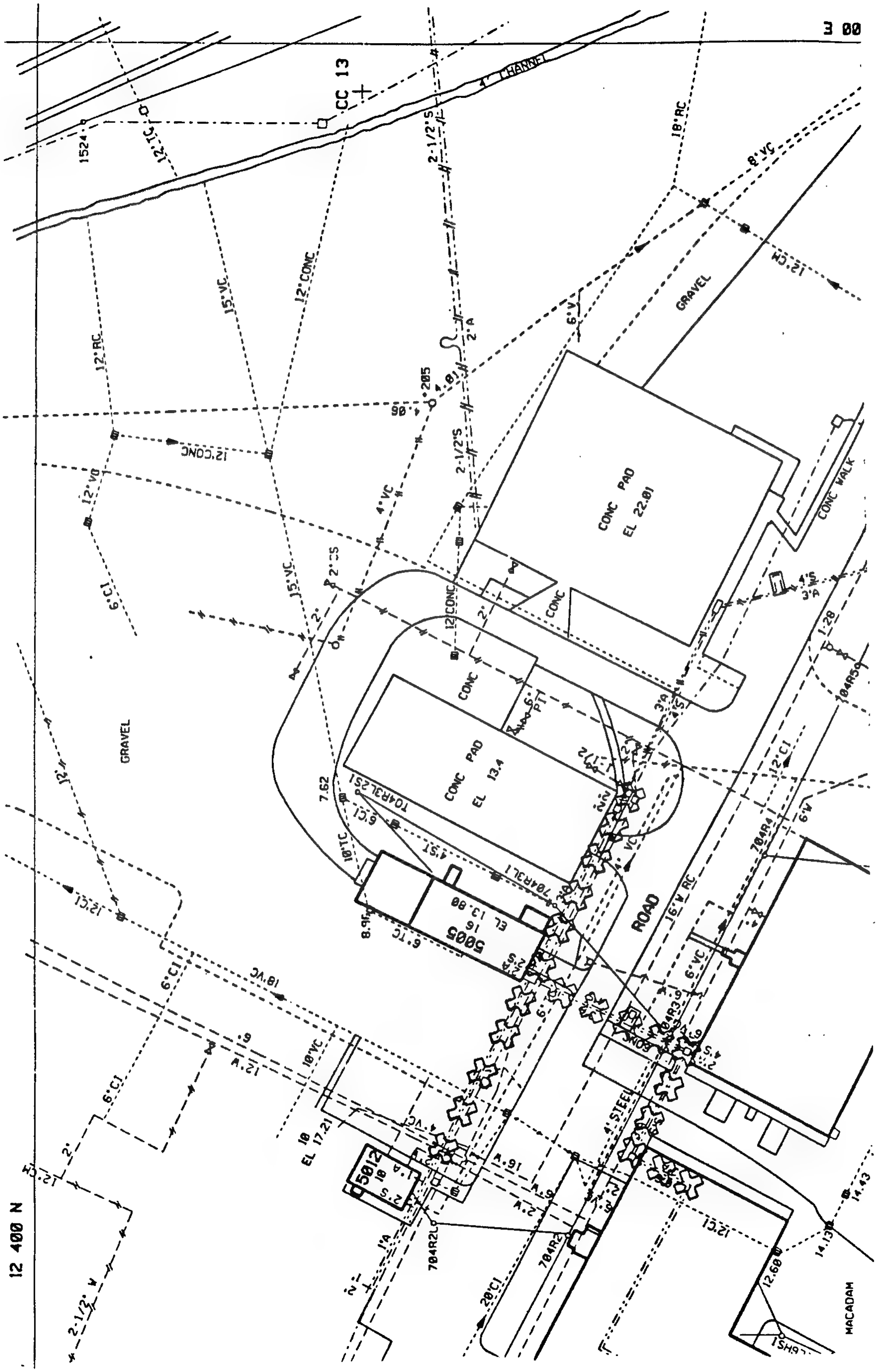


19M-3

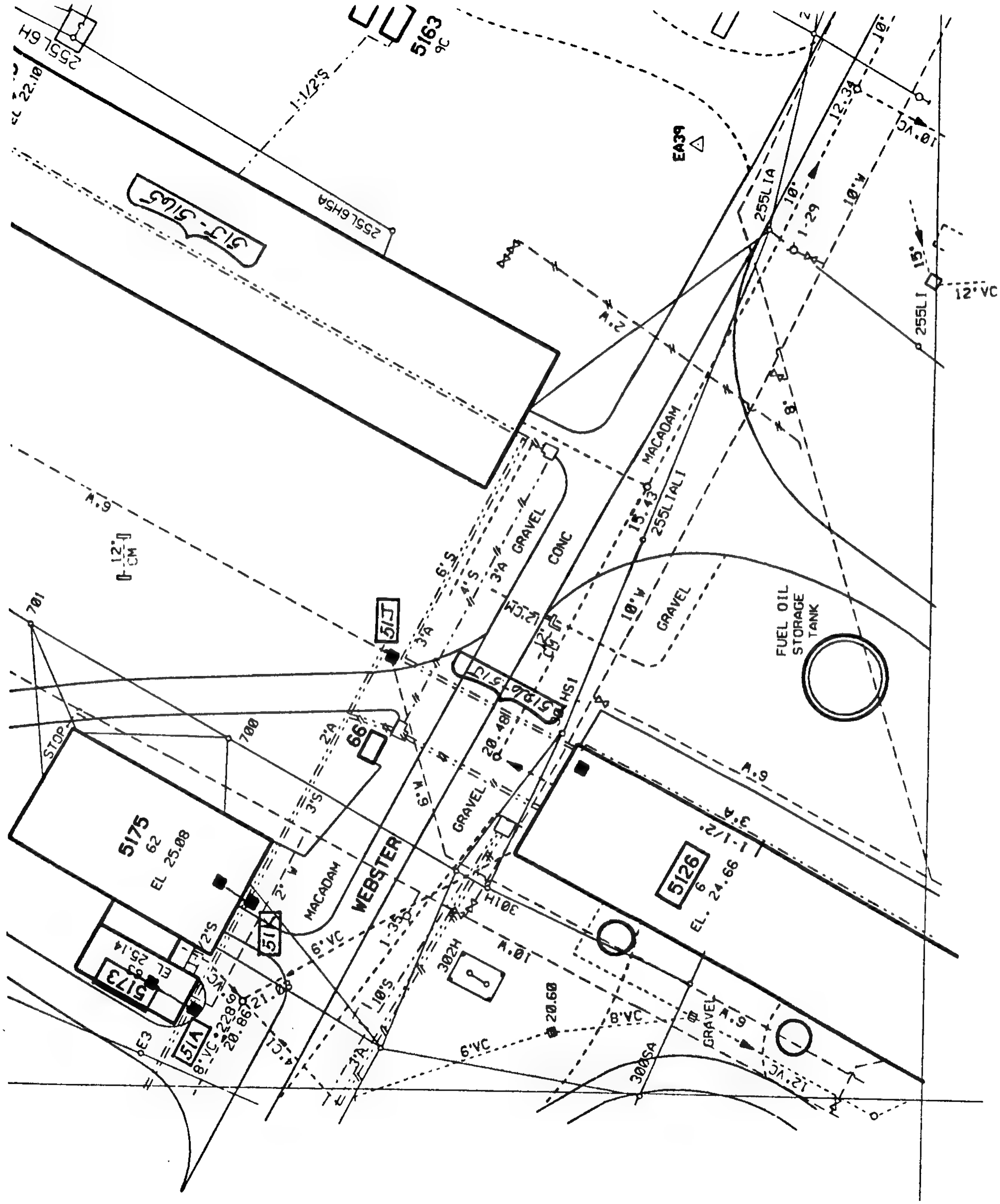

WEBSTER
ROAD
EA 102
EA 103
5188
5141
19M-4


BLACKHAWK
ELEC (UG)
705
704
703
702
704S
6'W
12'CM
GRAVEL
CONC WALK
5176
EL 22.21
10X6 CROSS
18'CM
5177
63A
EL 24.52
5179
309
EL.33.10
5178
308
2'W
FOUNDATION
2' CONDENSATE DISCHARGE
E4
E5
E6
13 300 E

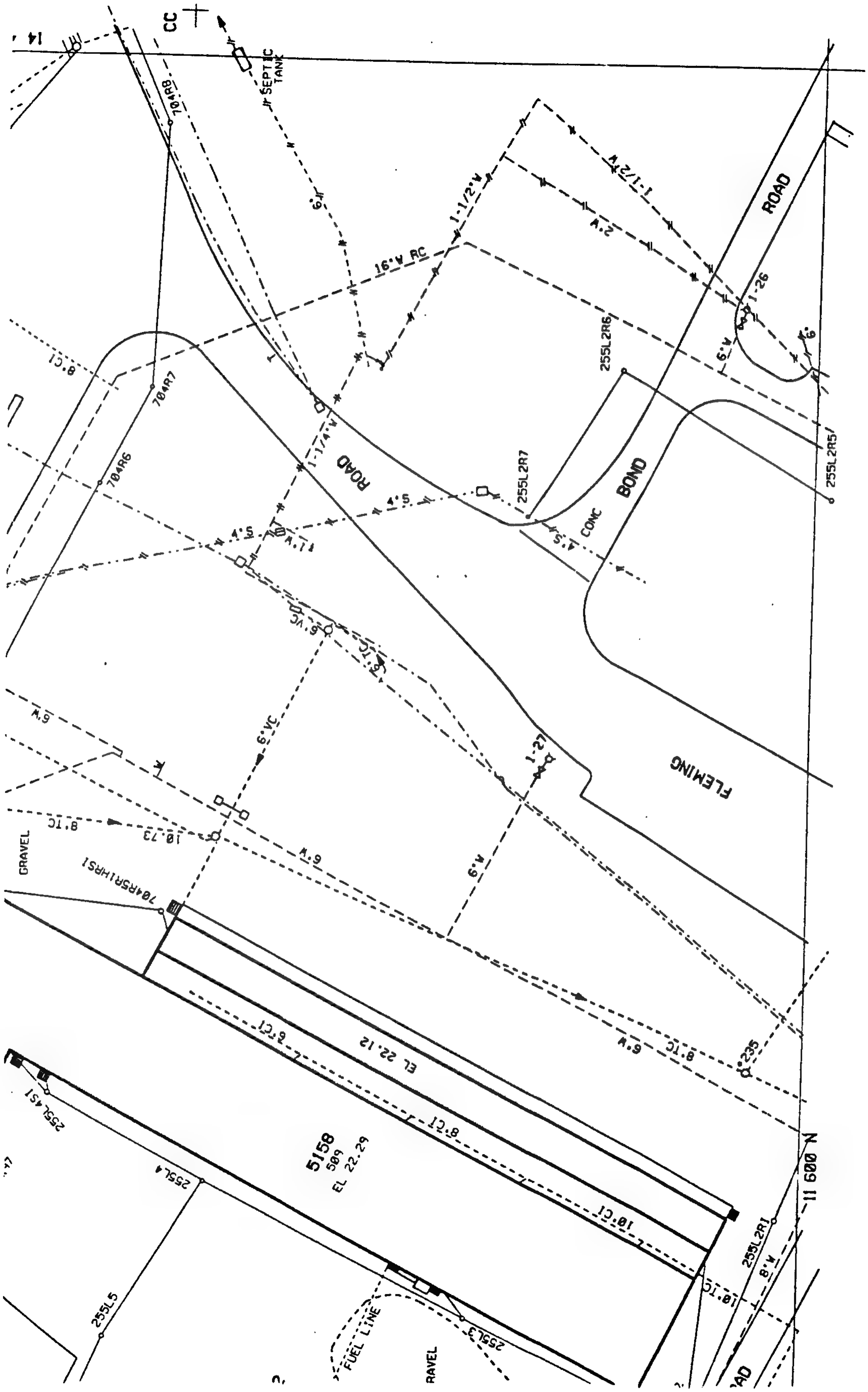
19N-1


3 00
12 400 N
CC 13
4' CHANNEL
GRAVEL
CONC PAD
EL 22.01
CONC PAD
EL 13.4
CONC
CONC WALK
ROAD
5005
5012
MACADAM

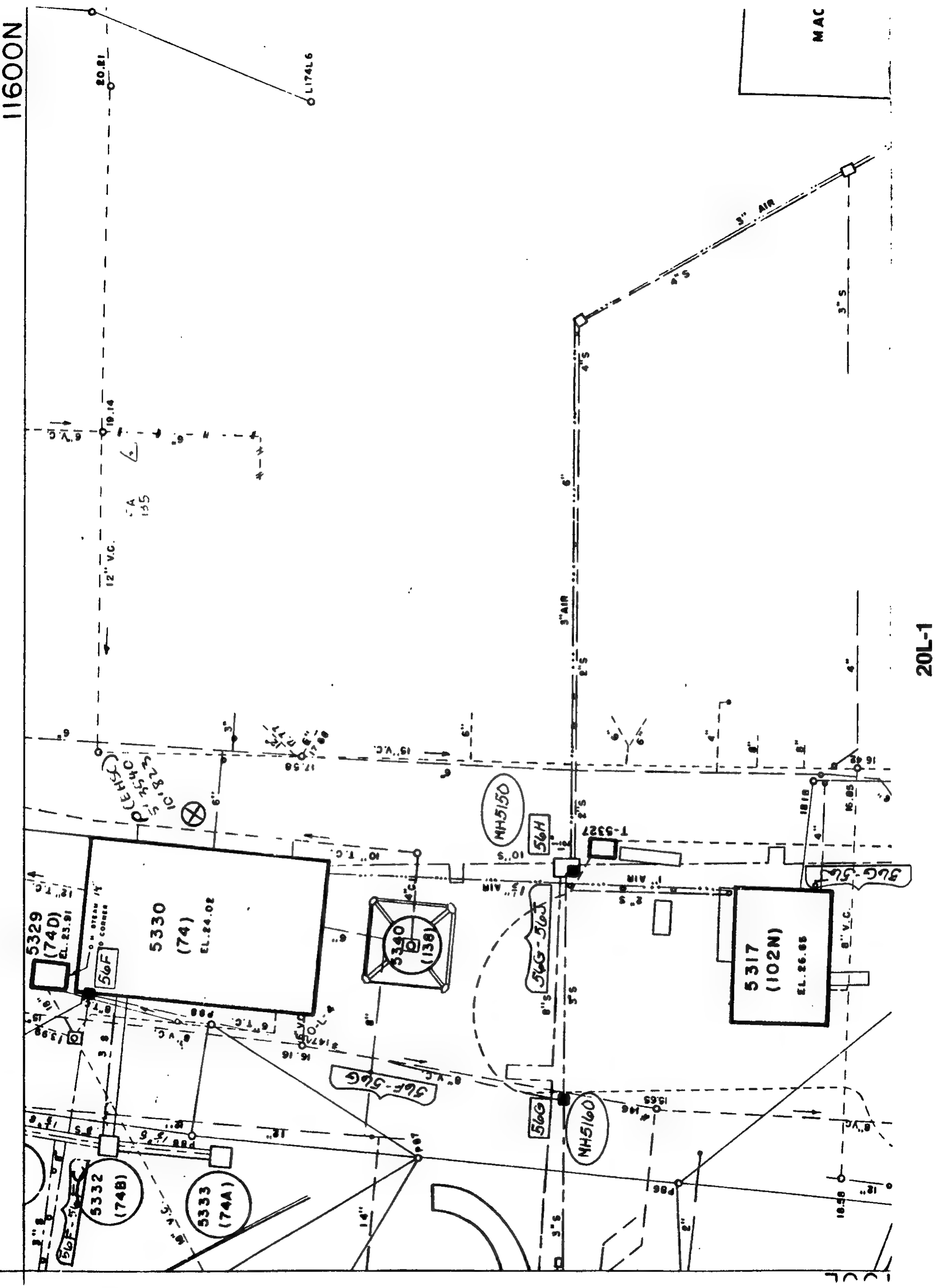
19N-2

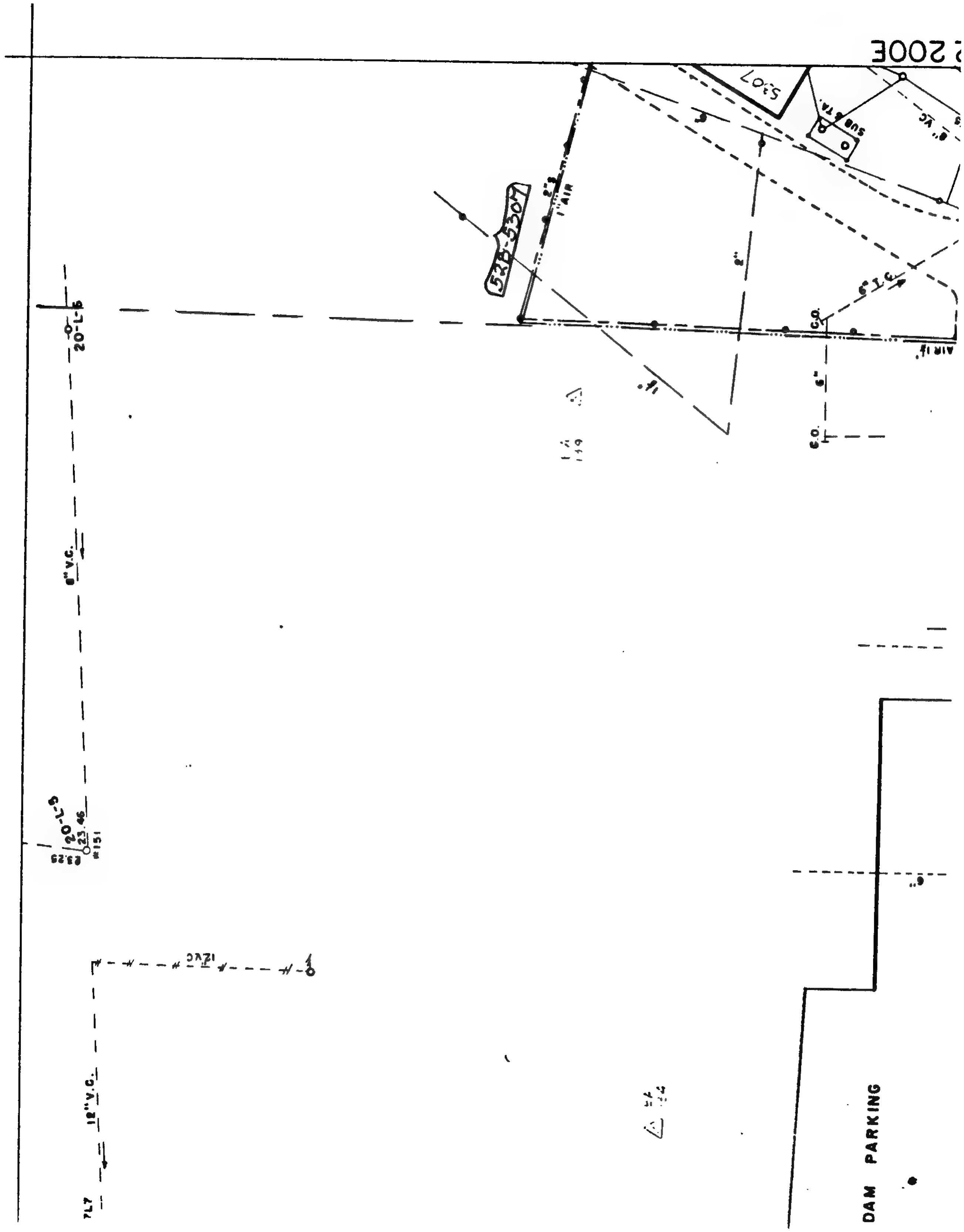

5163
5175
62
EL 25.08
5126
6
EL. 24.66
5173
WEBSTER
MACADAM
GRAVEL
CONC
FUEL OIL
STORAGE
TANK
255L1A
255L1
STOP

19N-3

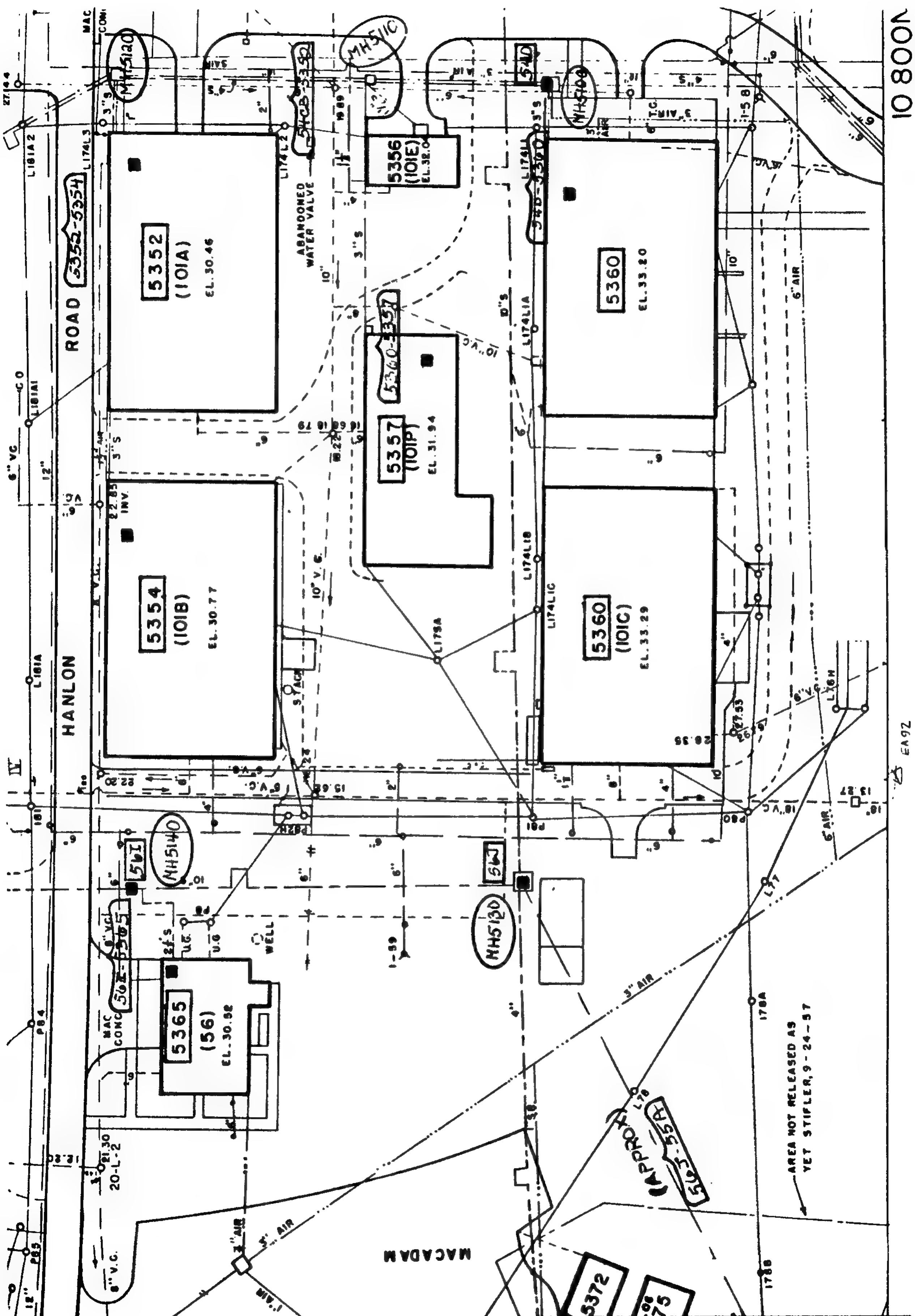

CC
SEPTIC TANK
704R8
704R7
704R6
1-1/2"W
2"W
16"W RC
6"
ROAD
1-26
255L2R6
255L2R5
255L2R7
1-1/4"W
ROAD
BOND
CONC
4"S
FLEMING
6"VC
1-27
6"W
GRAVEL
704RSR1HRS1
8"TC
10"73
EL 22.12
235
5158
509
EL 22.29
255L4
255L4S1
255L5
255L3
FUEL LINE
255L2R1
8"W
11 600 N
10"C

19N-4

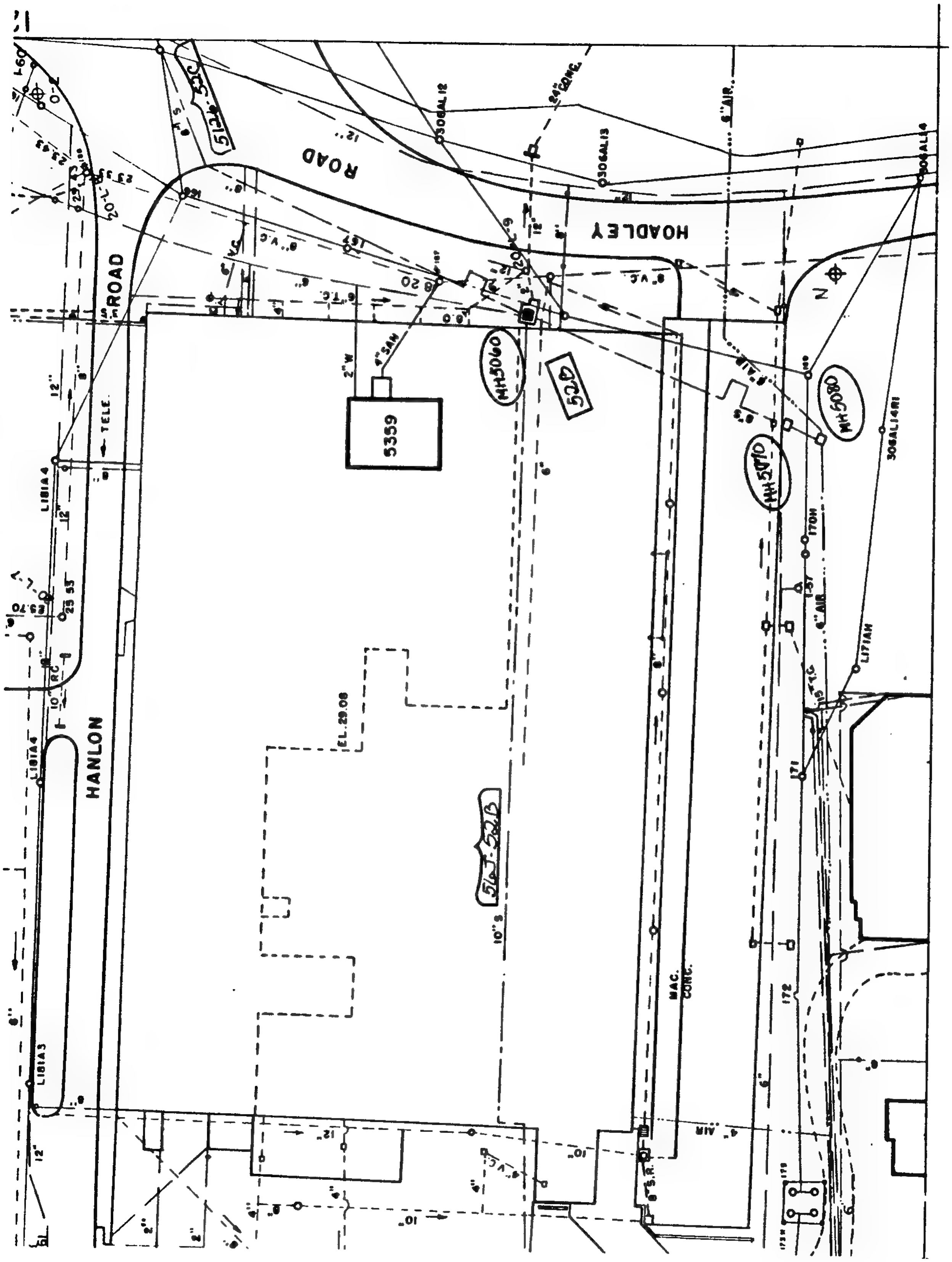

11600N
5329 (74D)
5330 (74)
5340 (138)
5317 (102N)
5332 (74B)
5333 (74A)
MH5150
MH5160
T-5327
3" AIR
12" V.C.
MAC
20L-1



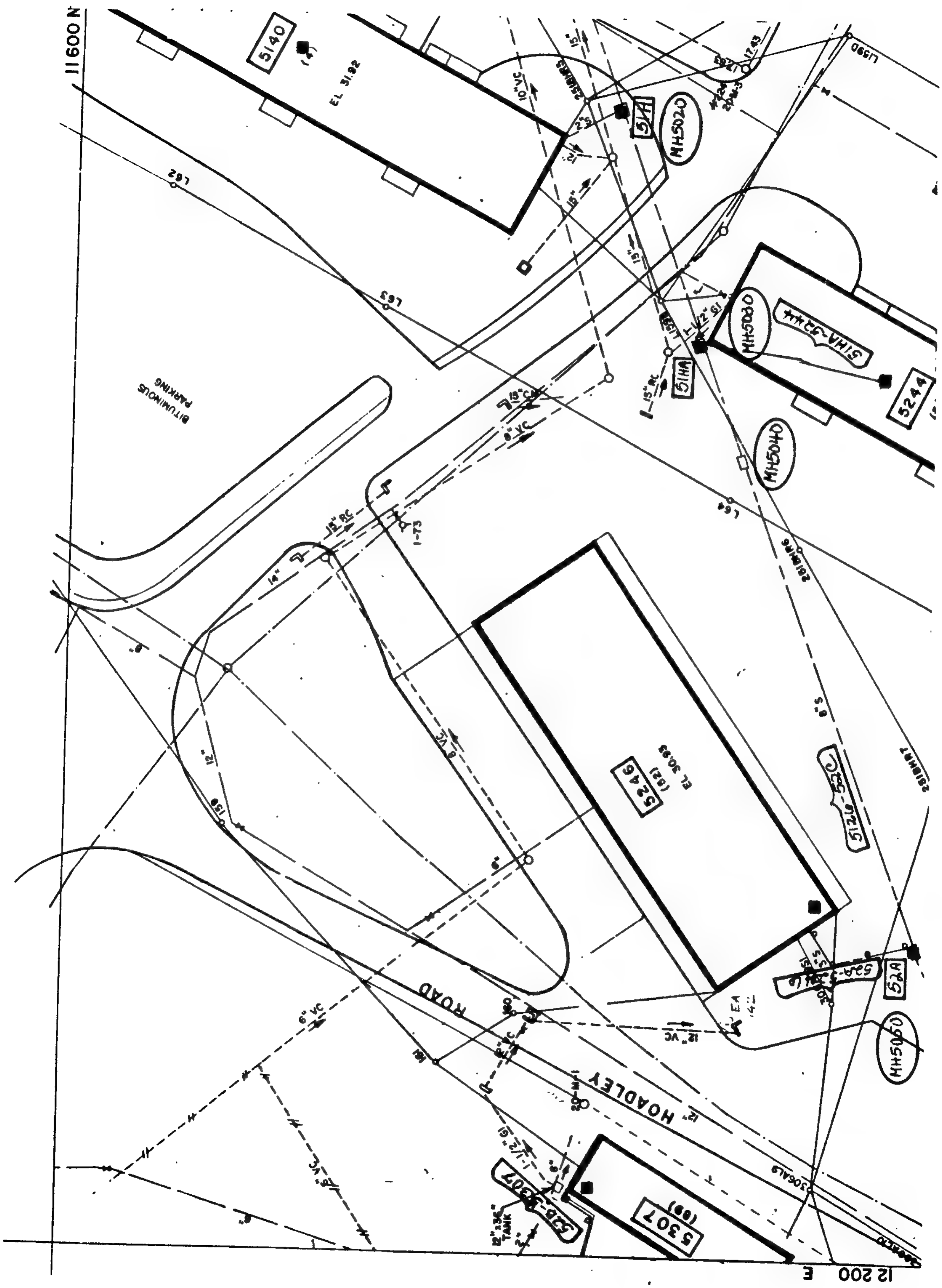
20L-2


HANLON ROAD
5352 (101A) EL. 30.46
5354 (101B) EL. 30.77
5356 (101E) EL. 32.0
5357 (101P) EL. 31.94
5360 (101D) EL. 33.20
5360 (101C) EL. 33.29
5365 (56) EL. 30.92
ABANDONED WATER VALVE
MACADAM
AREA NOT RELEASED AS YET STIFLER, 9-24-57
MH5130
MH5140
MH5110
5372
10 800
20-L-2

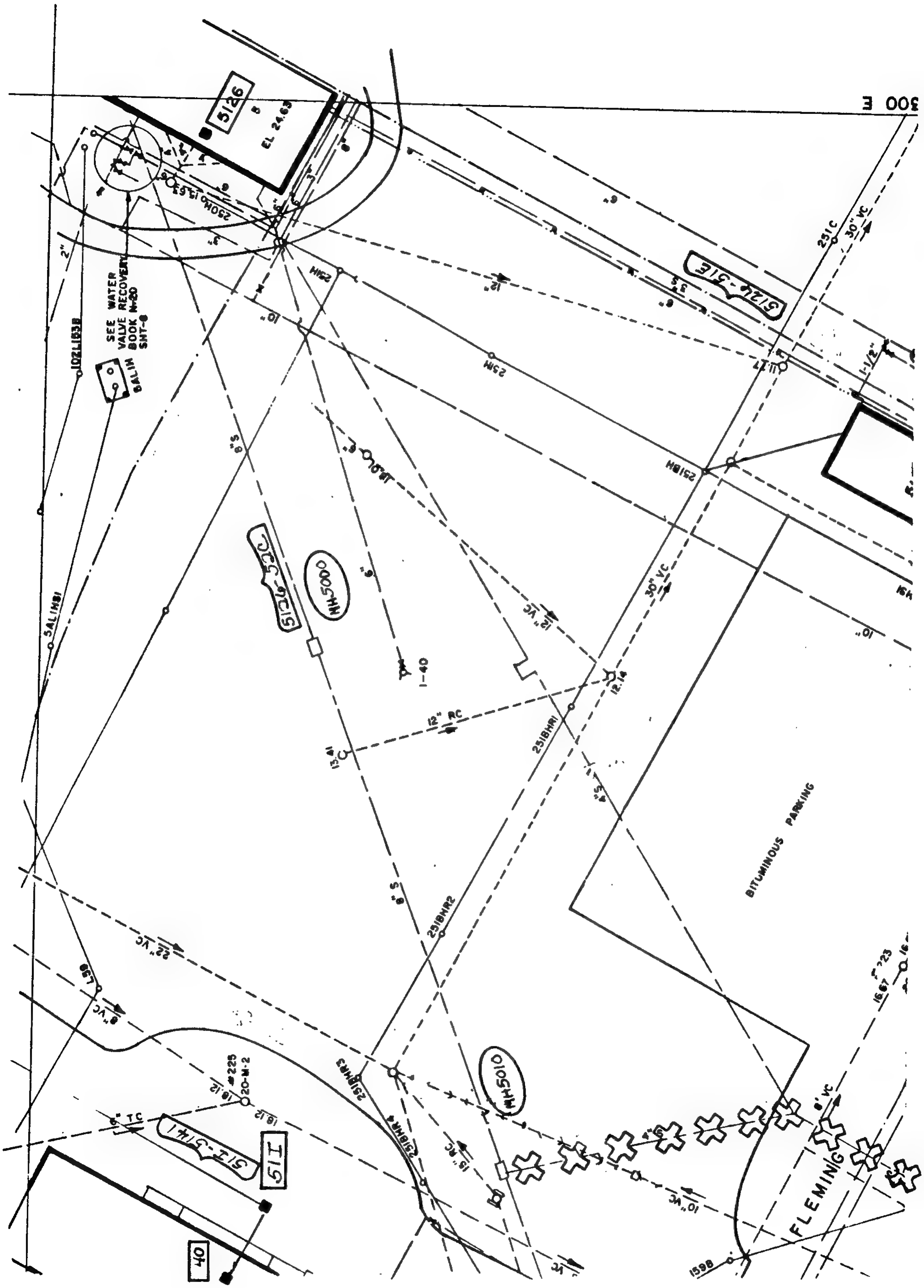
20L-3


HANLON
ROAD
HOADLEY
ROAD
5359
MH5060
MH5080
TELE.
EL. 29.08
MAC. CONC.

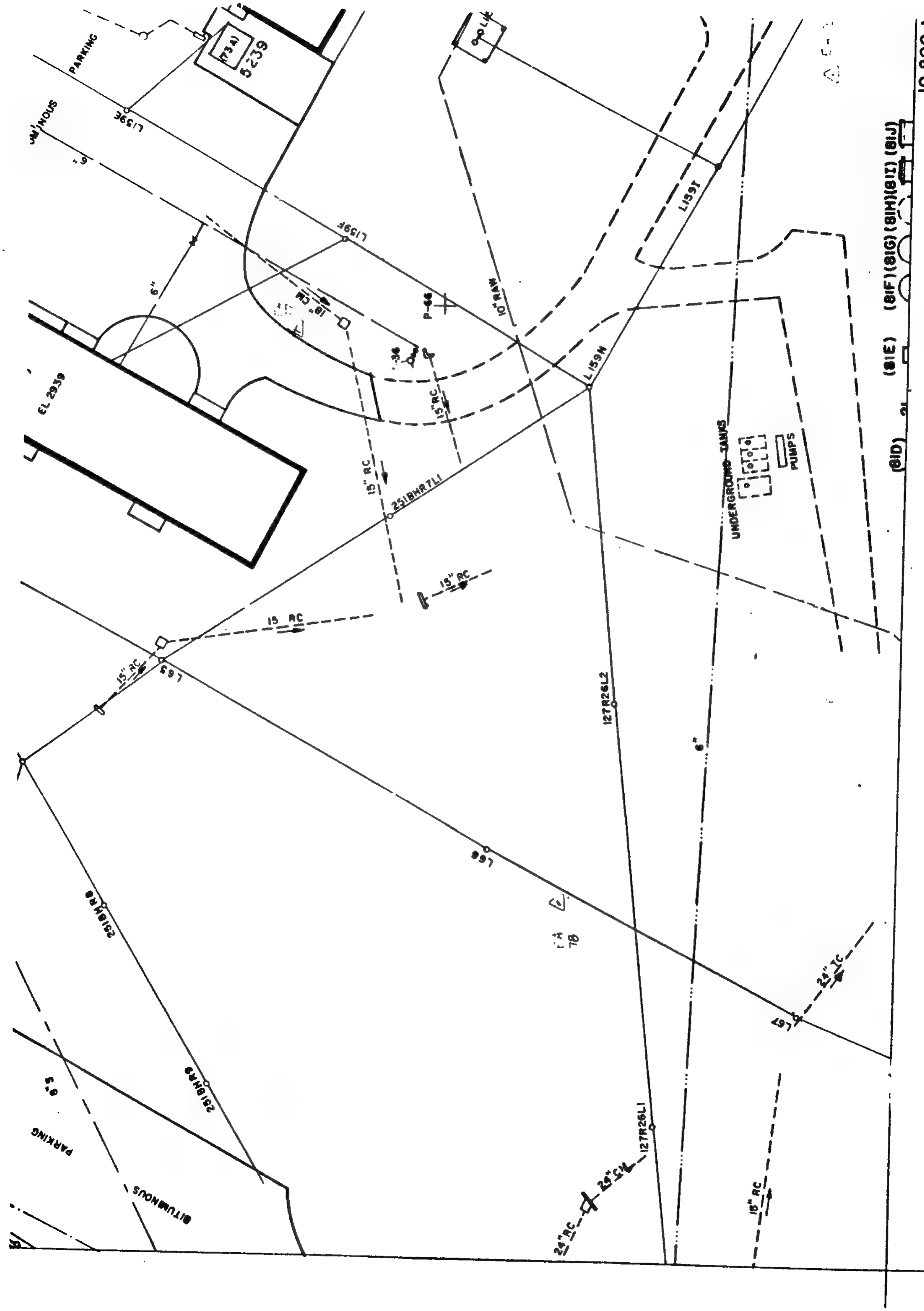
20L-4


11 600 N
5140
EL 31.92
BITUMINOUS PARKING
MH5020
MH5030
MH5040
MH5050
5244
5246
EL 30.63
HOADLEY ROAD
5307
12 200 E

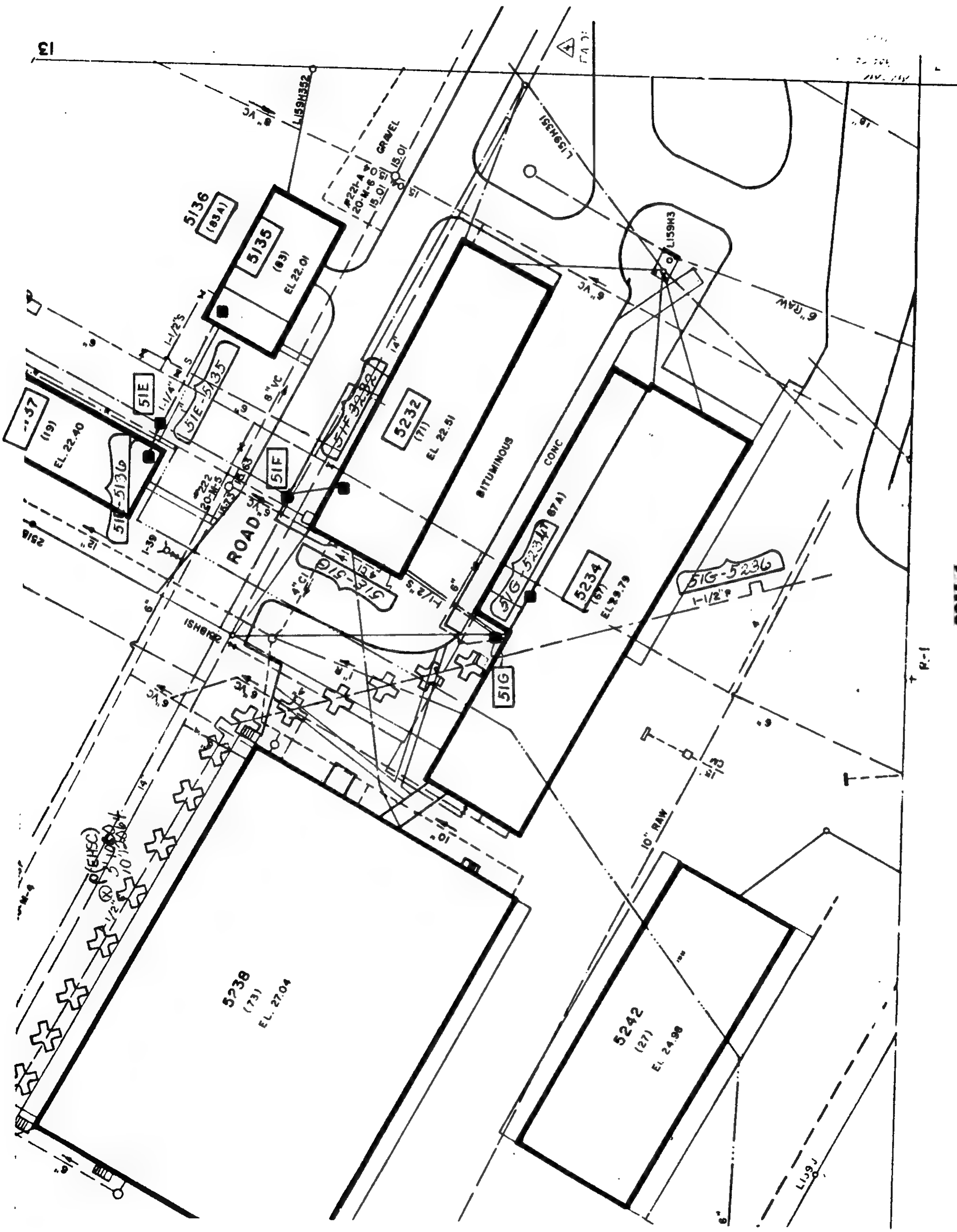
20M-1


5126
EL 24.63
SEE WATER
VALVE RECOVERY
BOOK N-20
SHT-8
MH5000
MH5010
12" RC
30" VC
22" VC
BITUMINOUS PARKING
FLEMING
1598

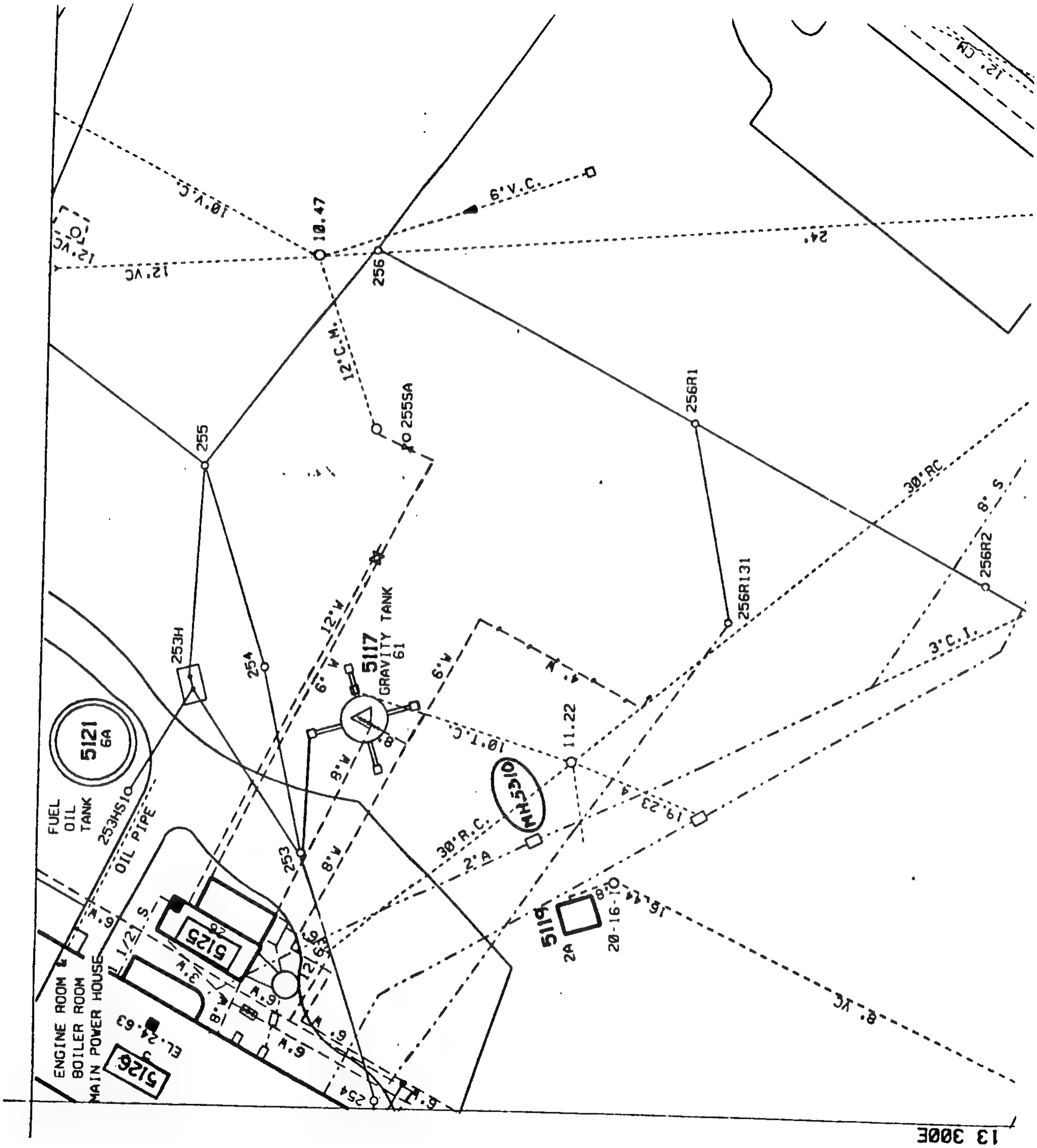
20M-2


PARKING
5239
(73A)
L159E
L159F
L159I
L159N
EL 2939
6"
18" CM
P-66
10" RAW
15" RC
25IBHR7LI
UNDERGROUND TANKS
PUMPS
(81E)
(81F)(81G)(81H)(81I)(81J)
(81D)
10 800 N
L63
L66
L67
127R26L2
127R26L1
251BHR8
251BHR9
24" TC
24" RC
24" C N
BITUMINOUS
PARKING

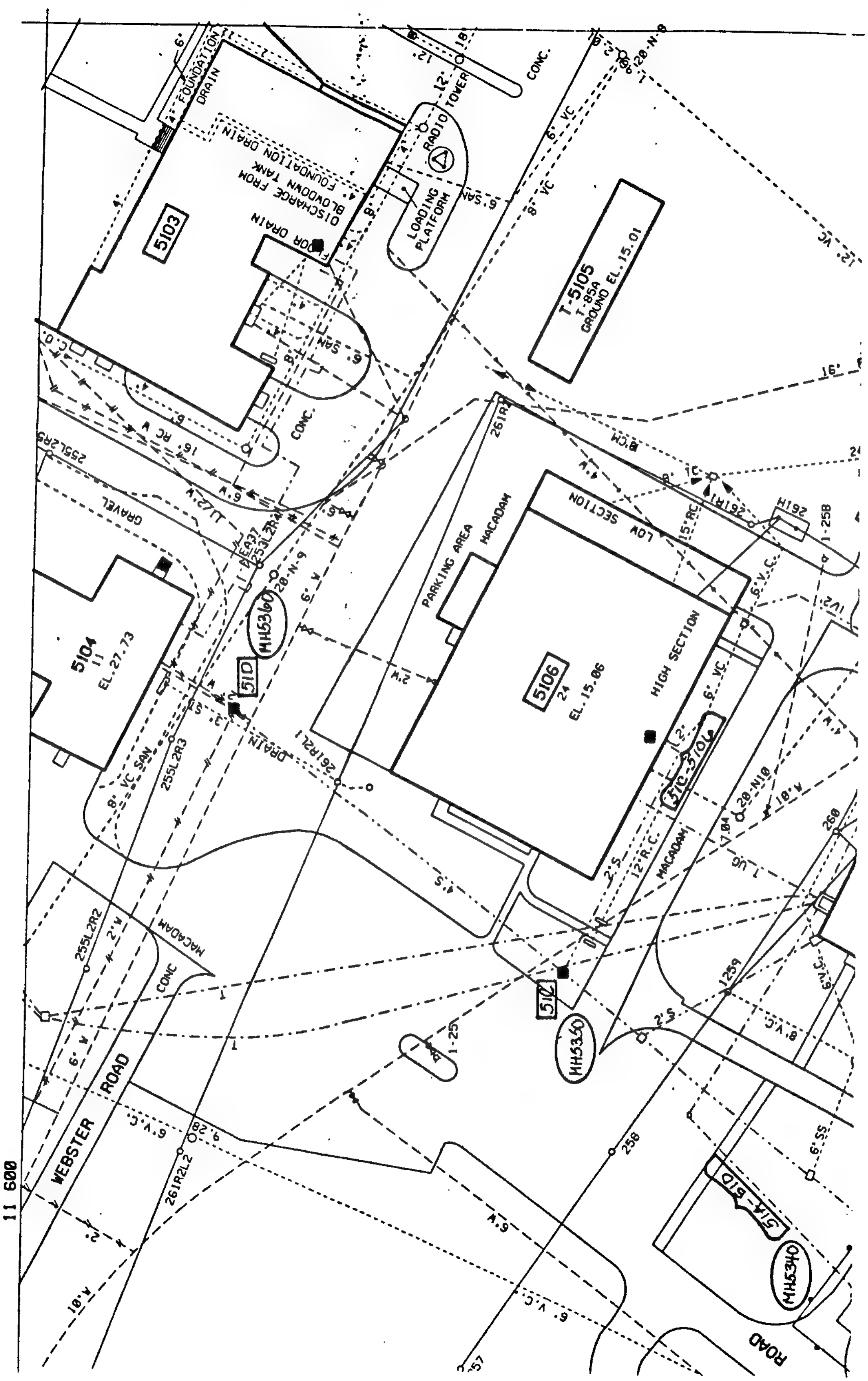
20M-3


5136
5135
EL 22.01
GRAVEL
5232
(71)
EL 22.51
BITUMINOUS
CONC
ROAD
5234
(67)
51E
51F
51G
5238
(73)
EL. 27.04
5242
(27)
EL 24.98
10" RAW
6" RAW
8" VC

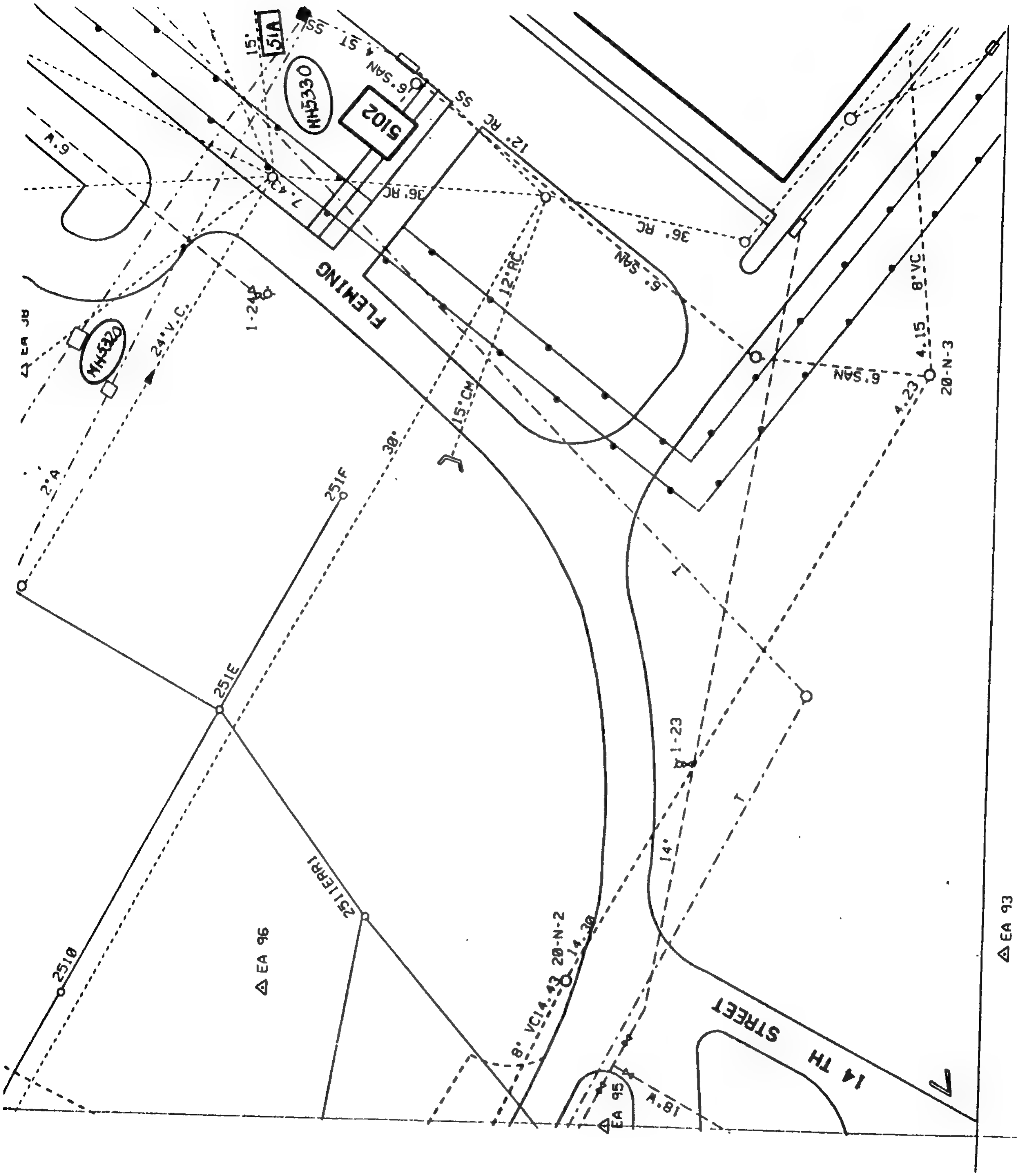
20M-4


FUEL OIL TANK
5121
6A
253HS10
OIL PIPE
ENGINE ROOM & BOILER ROOM MAIN POWER HOUSE
5125
5126
EL. 24.63
253H
253
254
255
255SA
256
256R1
256R131
256R2
10.47
11.22
5117
GRAVITY TANK
61
MH5310
5119
2A
20-16-10
12"V
6" W
8" W
6" W
10" V.C.
12" VC
12" C.M.
6" V.C.
24"
30" RC
30" R.C.
8" S.
3" C.I.
10" C.I.
19.23
2" A
8" VC
12" CM
13 300E

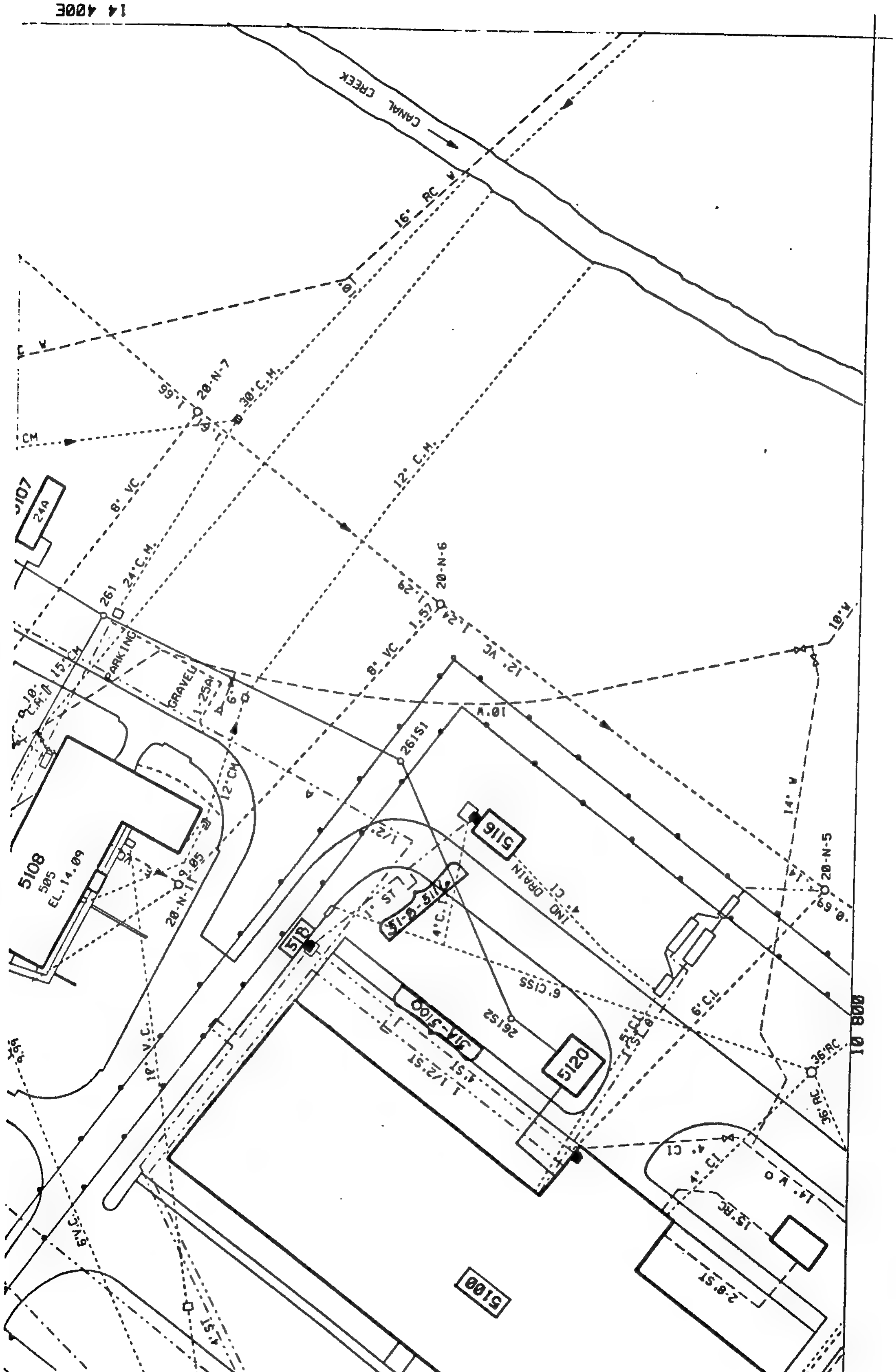
20N-1


5103
FOUNDATION DRAIN
DISCHARGE FROM BLOWDOWN TANK FOUNDATION DRAIN
FLOOR DRAIN
RADIO TOWER
LOADING PLATFORM
CONC.
T-5105
T-854
GROUND EL.15.01
5104
11
EL.27.73
5106
24
EL.15.06
HIGH SECTION
LOW SECTION
PARKING AREA
MACADAM
GRAVEL
MH5360
MH5350
MH5340
WEBSTER ROAD
ROAD
11 600

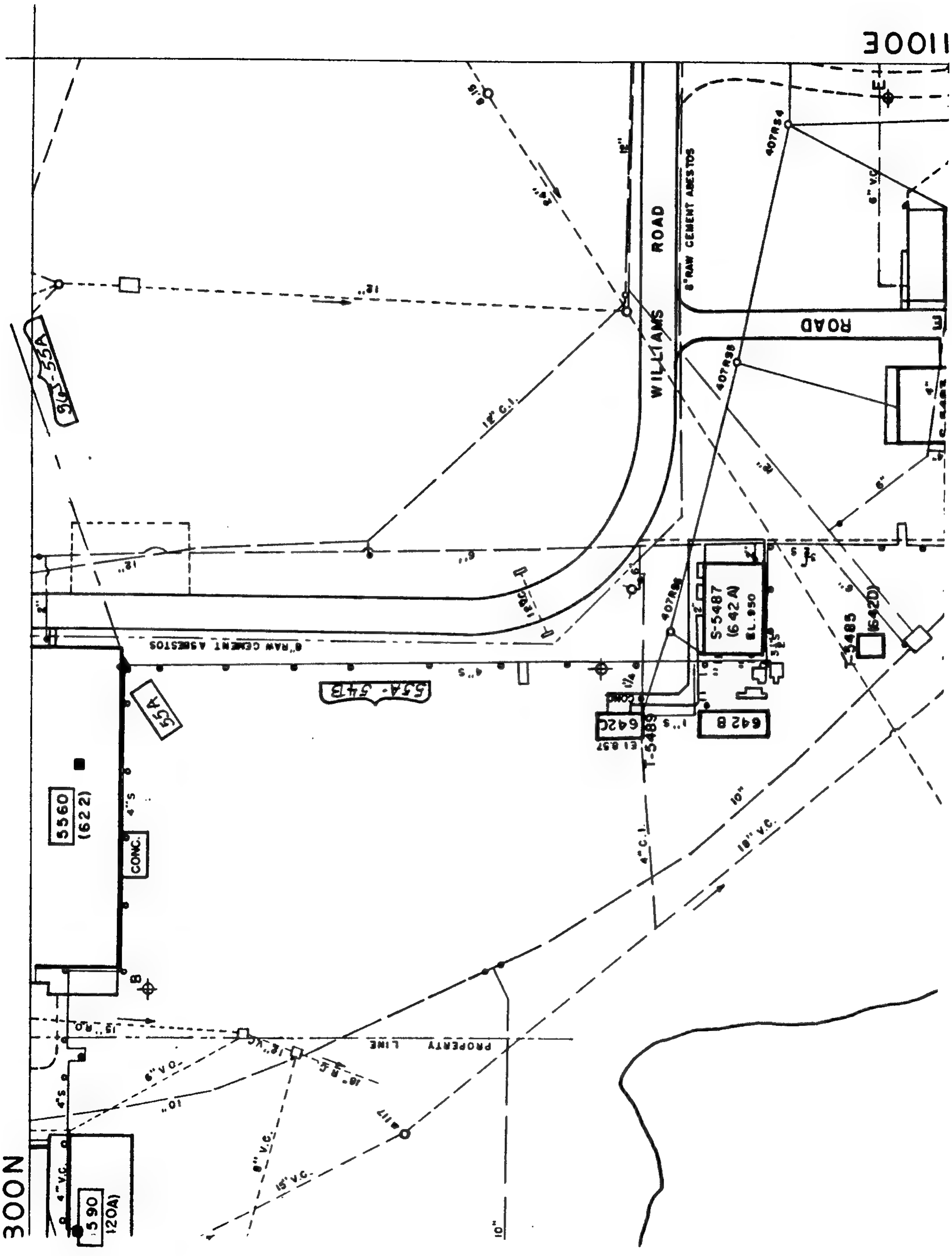
20N-2


FLEMING
14 TH STREET
5102
51A
MH5330
MH5320
36" RC
12" RC
6" SAN
15" CM
30"
8" VC
24" V.C.
251E
251F
2510
251ERR1
20-N-2
20-N-3
EA 96
EA 95
EA 93
1-23
1-24

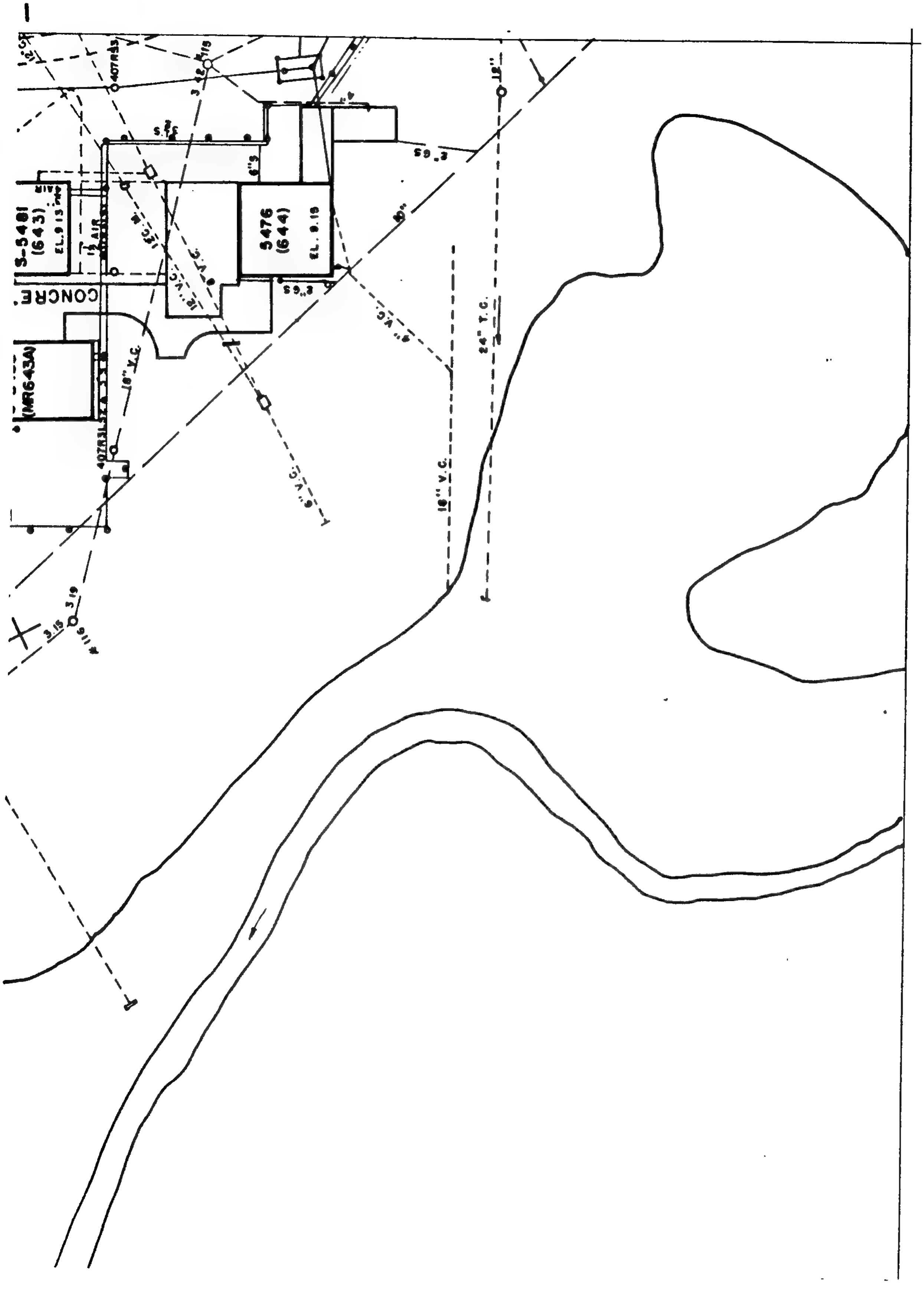
20N-3


14 400E
CANAL CREEK
10 800
5107
5108
5116
5120
5100
20-N-7
20-N-6
20-N-5
PARKING
GRAVEL
IND. DRAIN

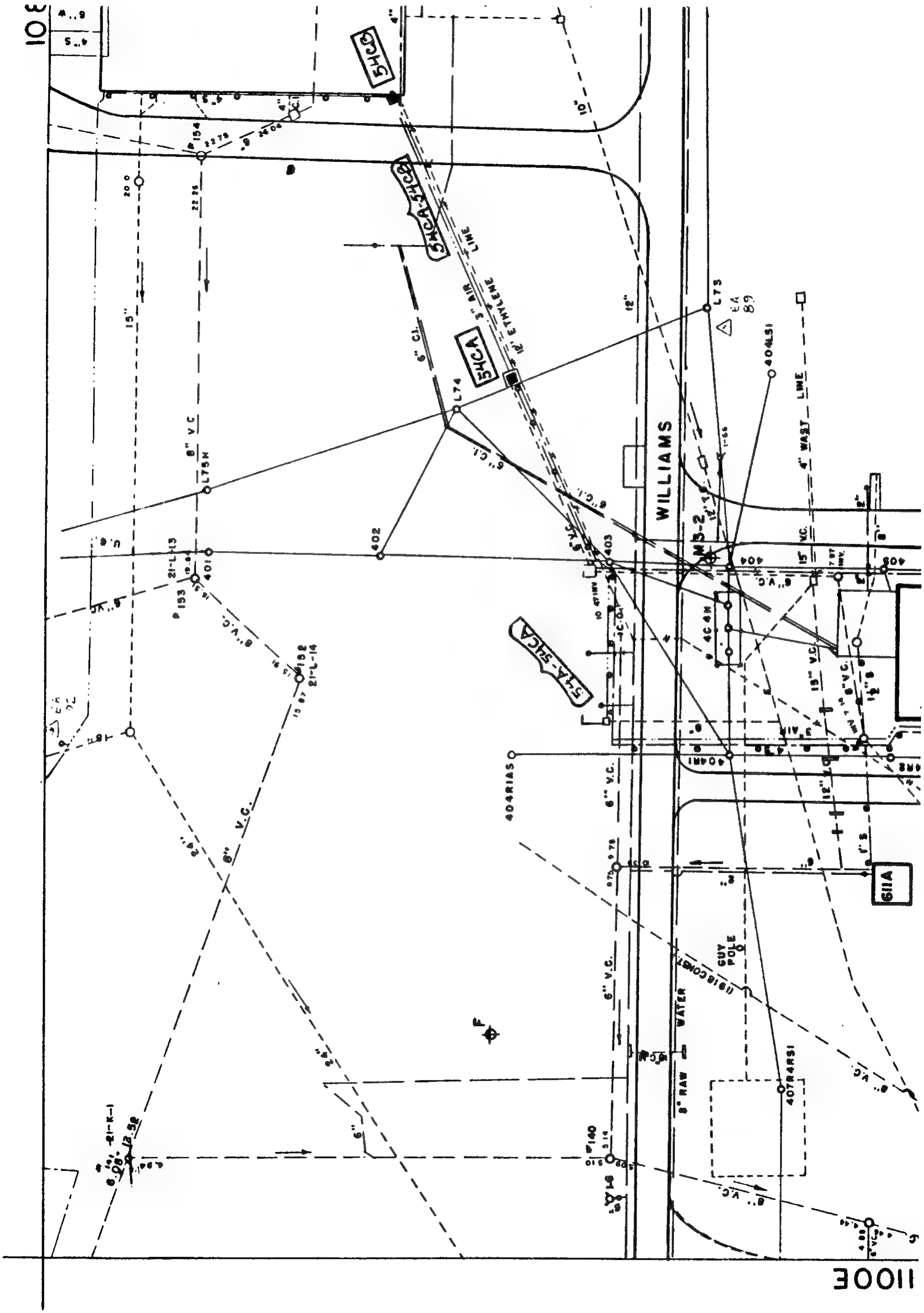
20N-4

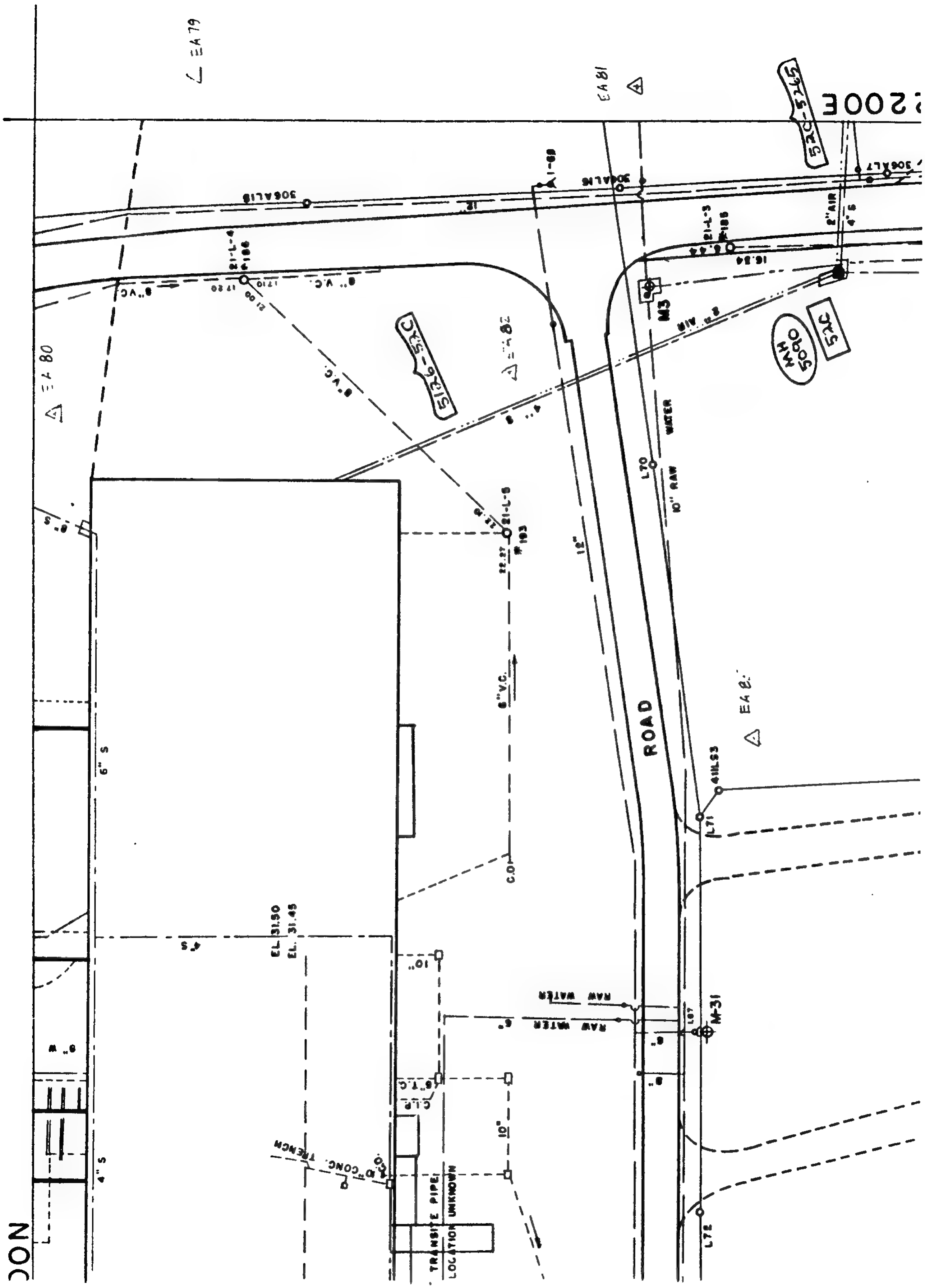

WILLIAMS ROAD
ROAD
8"RAW CEMENT ABESTOS
8"RAW CEMENT ASBESTOS
PROPERTY LINE
5560
(622)
CONC.
55A
55A-54B
S-5487
(642 A)
642 B
642C
T-5489
T-5485
(642D)
1100E
300N
590
(20A)
10"
18" V.C.
15" V.C.
4" C.I.
12" C.I.

21K-2

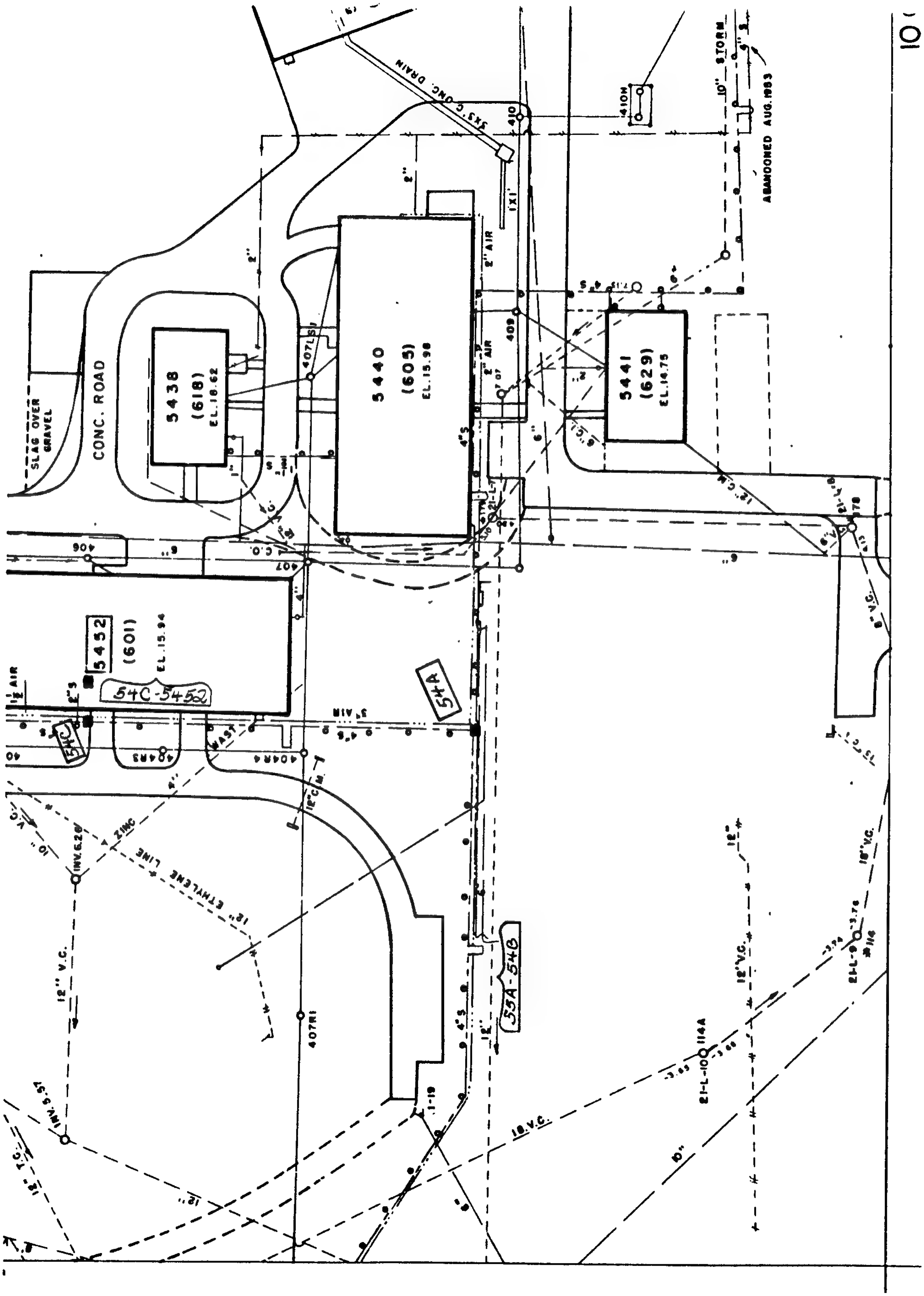


21K-4

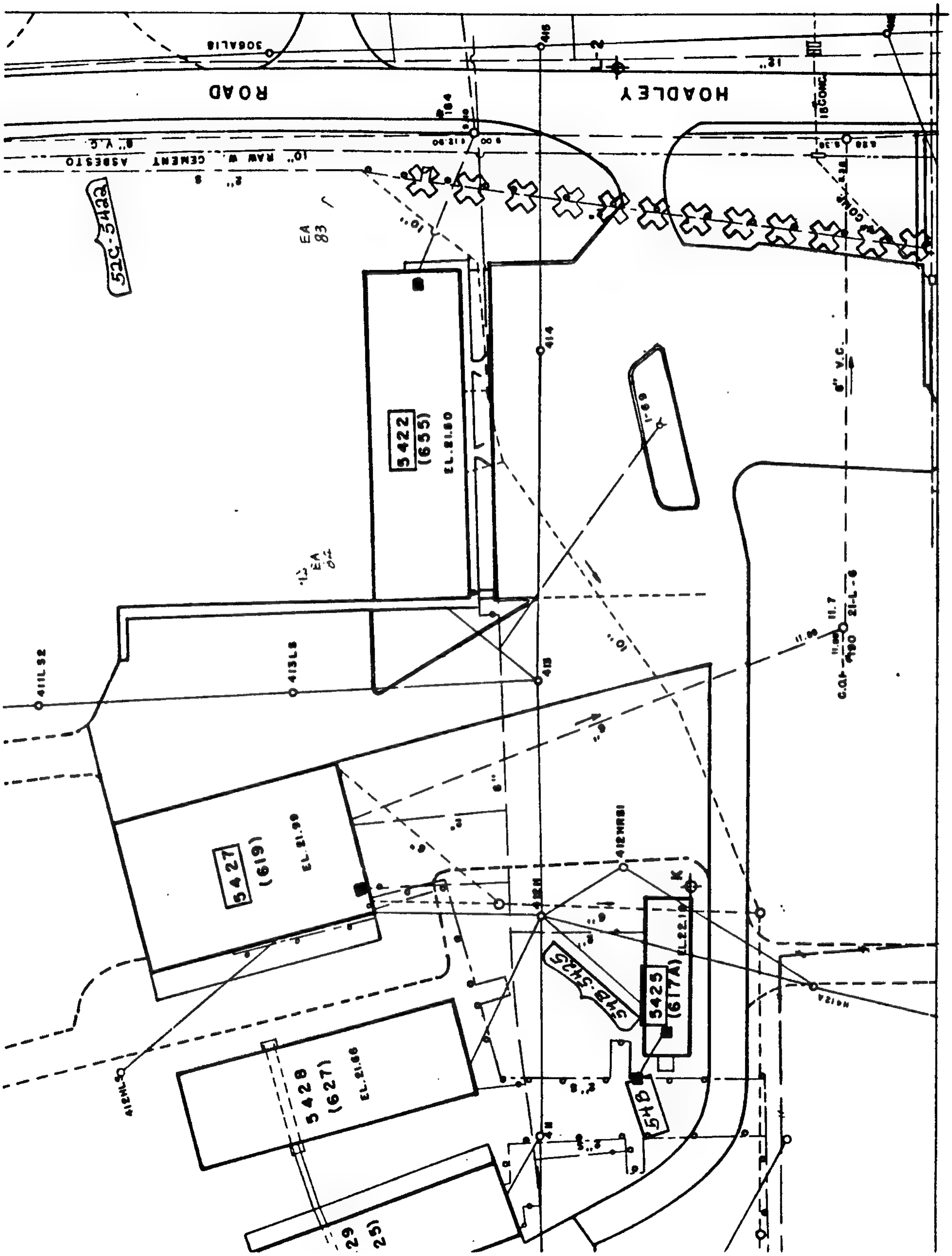

WILLIAMS
21L-1
54CB
54CA-54CB
54CA
54A-54CA
611A
12" ETHYLENE
3" AIR LINE
4" WAST LINE
GUY POLE
8" RAW WATER
1100E


ROAD
10" RAW WATER
RAW WATER
TRANSITE PIPE LOCATION UNKNOWN
M3
M-31
L70
L71
L72

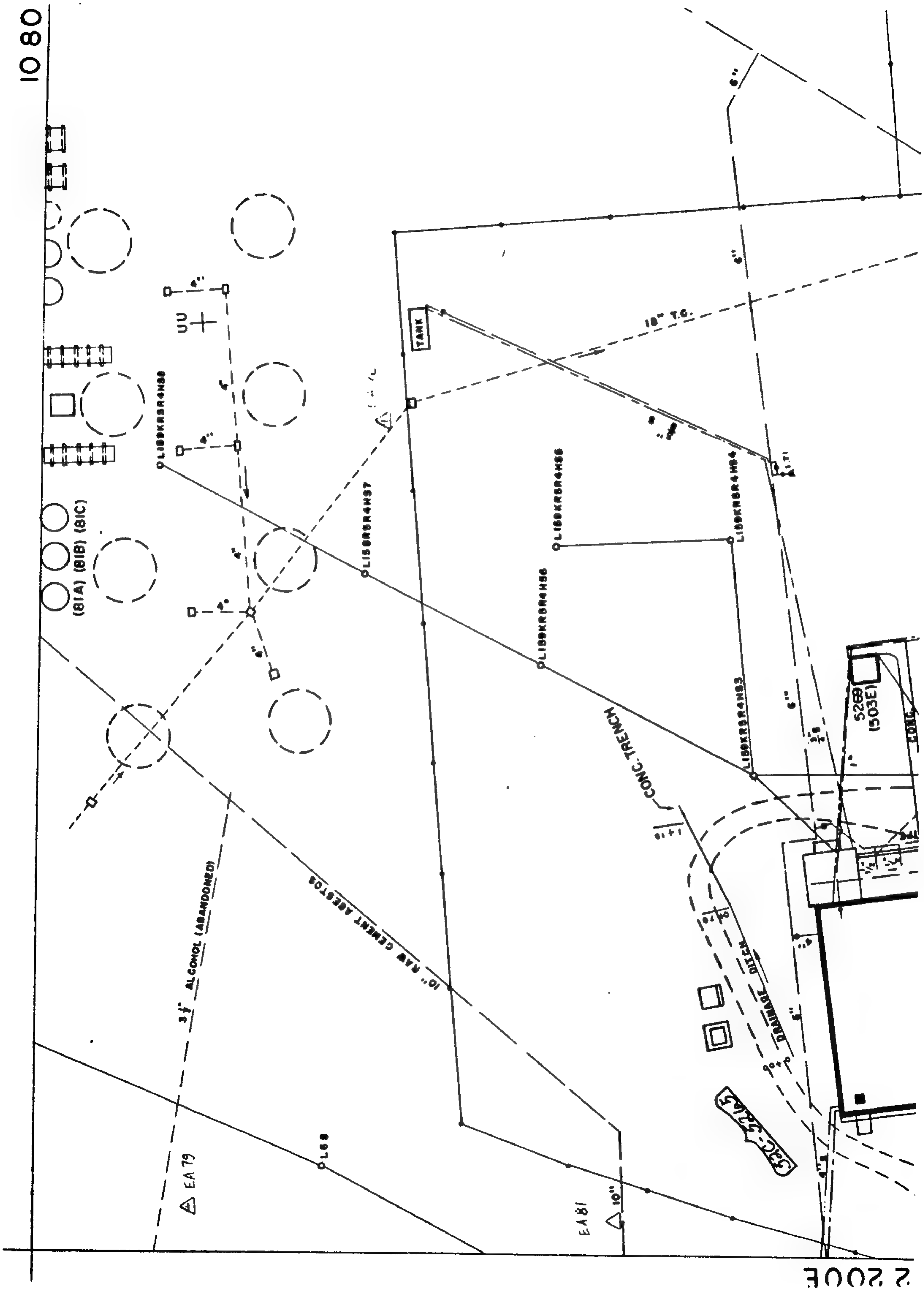
21L-2


CONC. ROAD
SLAG OVER GRAVEL
5438
(618)
EL.16.62
5440
(605)
EL.15.98
5441
(629)
EL.14.75
5452
(601)
EL.15.94
54C-5452
54C
54A
53A-54B
5x5 C. CONC. DRAIN
10" STORM
ABANDONED AUG.1983
12" ETHYLENE LINE
12" V.C.
18" V.C.

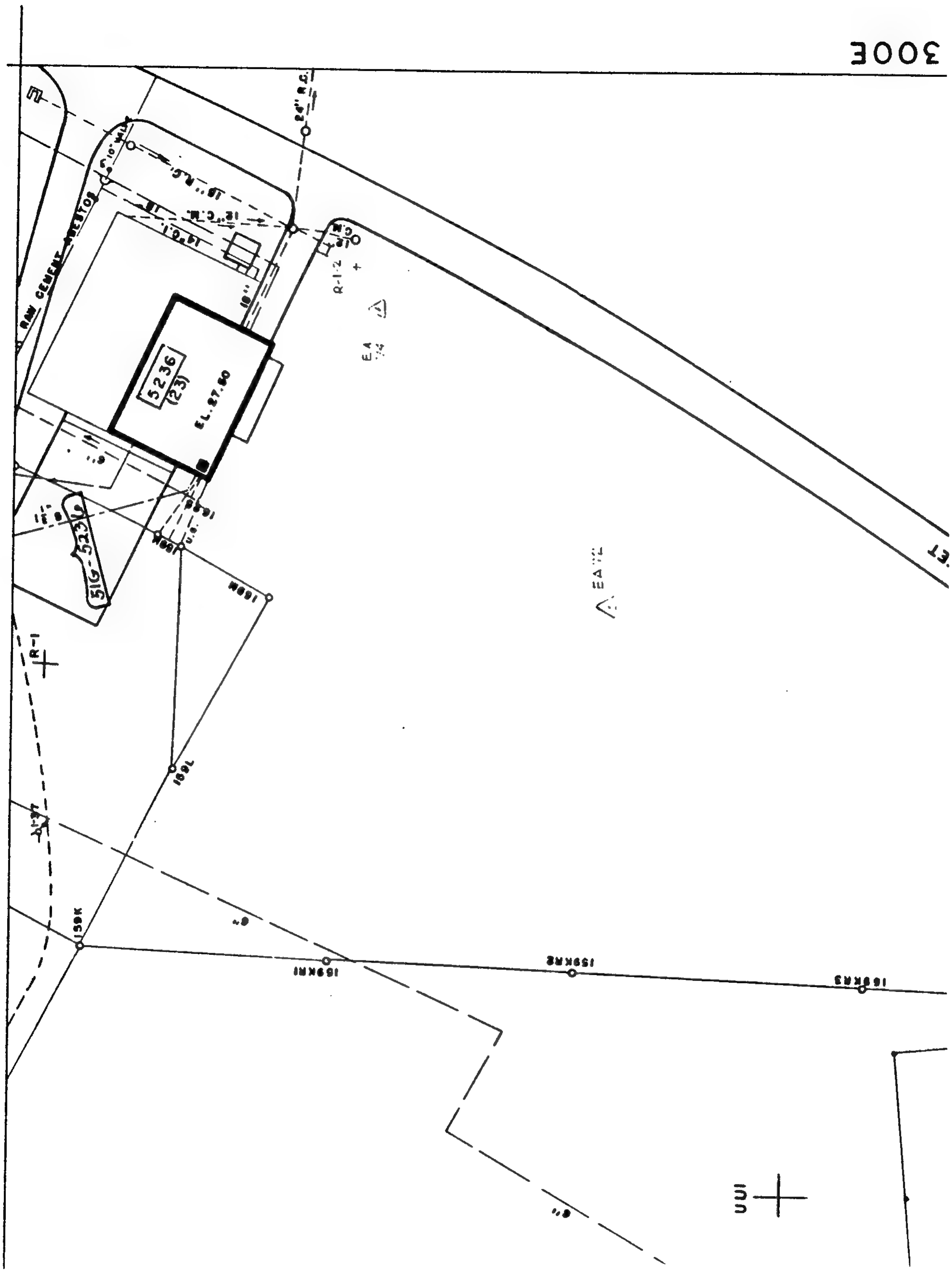
21L-3



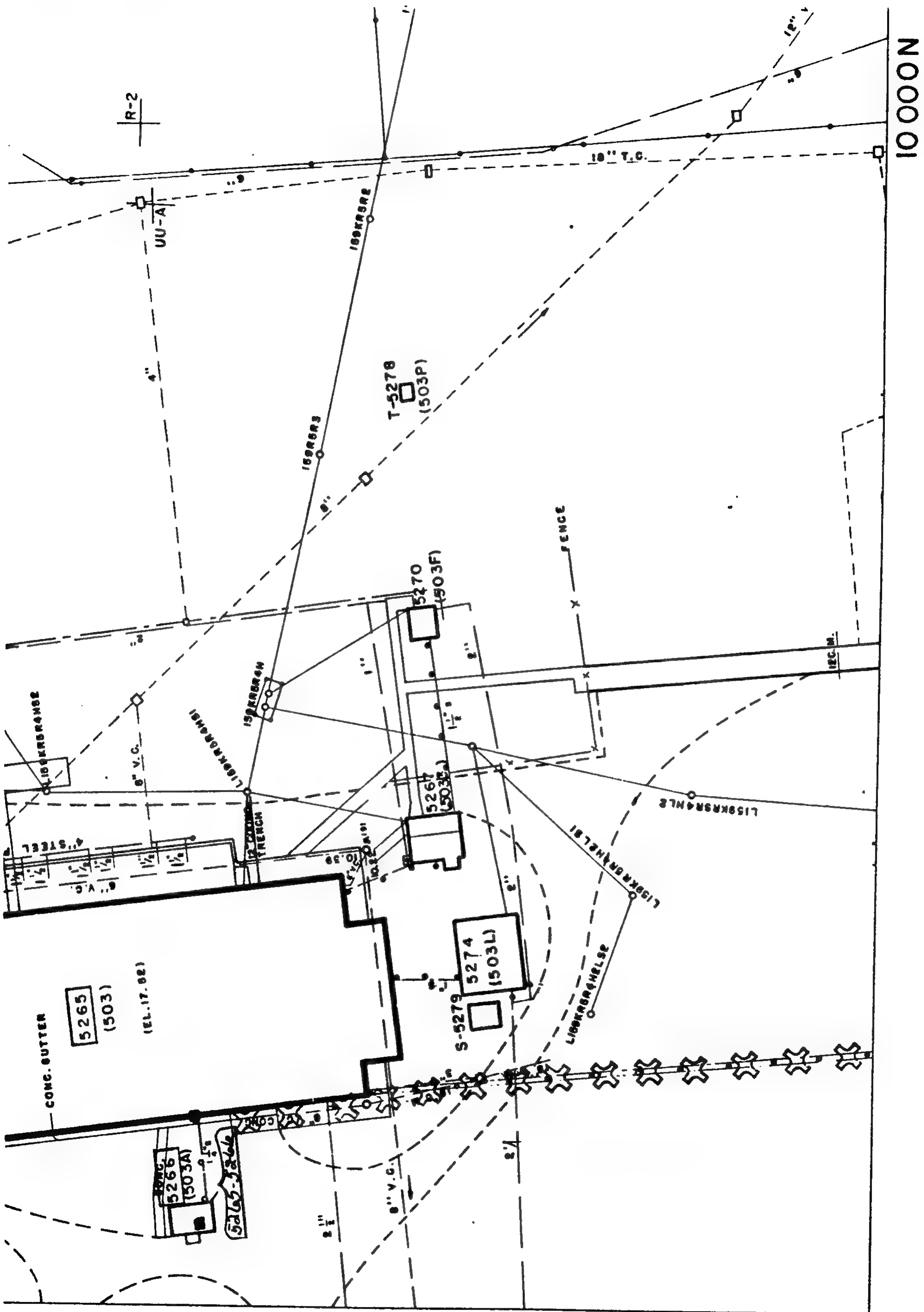
21L-4


10 80
2 200E
(81A) (81B) (81C)
TANK
18" T.C.
CONC. TRENCH
5269
(503E)
CONC.
DRAINAGE DITCH
10" RAW CEMENT ABESTOS
3½" ALCOHOL (ABANDONED)
EA 79
EA 81
10"

21M-1



21M-2


10 000N
R-2
UU-A
T-5278
(503P)
5270
(503F)
5265
(503)
5274
(503L)
S-5279
5266
(503A)
FENCE
CONC. GUTTER
18" T.C.

21M-3

Appendix B: Pipe Section and Manhole Inventory Spreadsheets for Edgewood Area Heat Distribution Piping

Overview

An inventory of the pipe sections and manholes at EA was prepared from the information supplied by DPW personnel, information on the utility maps, and the findings of the system survey. This information has also been stored electronically in a computer spreadsheet to serve as a living reference document for DPW personnel. To facilitate the identification of distribution system sections for use during the condition survey, an identification scheme was developed based on node numbers. The node numbers are shown on the maps in Appendix A. Pipe sections are identified by the node numbers of the section endpoints. Data on the pipe sizes, materials of construction, age, and other aspects were compiled for each section to the extent possible with the information available. In addition, locations of the manholes were tabulated. It is recommended that the computer version of the spreadsheet be updated as changes are made to the system.

Explanatory Notes for Pipe Section Table

Table B1 contains pipe section inventory data. The SECTION ID column contains the Section Identification as described above. To assist with pipe section location, the MAP SHT contains the number of the 40-scale map sheet(s) upon which the pipe section appears. The FROM LOCATION and TO LOCATION columns give the location of the section's endpoints. The OH/UG column notes whether the section is overhead/aboveground (OH) or underground (UG). The STM DIAM column gives the diameter

of the steam line in inches. The R DIAM column gives the diameter of the condensate line (if any) in inches. The LENGTH column gives the length of the section in feet. The MAT CODE column gives the material of construction as follows:

MAT CODE	EXPLANATION OF MATERIALS USED
AG	Aboveground - Insulated & Aluminum-Cased Piping Mounted on Steel Poles, Concrete Piers, or Wood Trestles
RW	Prefabricated (Ricwil) Metal Casing, Heavy Coal Tar Coating
T	Buried Tile (Terra Cotta) System
S-WY	Steel Cast in Wyecor, Direct Buried, No Casing
S-PR	Steel Wrapped with Fiberglass Insulation + Vapor Barrier Surrounded by Protexulate, Direct Buried, No Casing
FGR	Fiberglass-Reinforced Plastic Condensate Return Line

The YEAR INST column gives the approximate year of pipe installation. Exact years were not available. Several locations were identified as NEW. This pipe was installed within the last 10 years, but an exact year was not available. The SUMMER column notes whether or not the section is on or off during the summer. An entry of SOME in this column denotes that the line is used intermittently in the summertime, based on demand.

Explanatory Notes for Manhole Table

Table B2 contains manhole inventory information. A manhole numbering scheme was set up to facilitate the identification of the manholes so that inspection comments could be correlated to them. In general, manhole identifications were assigned for each area beginning at the heating plant and proceeding around the loop. The manholes closest to the plant in each area (E3312, E4160, and E5126) were assigned the numbers 3000, 4000, and 5000, respectively. Identification numbers were assigned to subsequent manholes based upon increments of 10. For example, in the 3000 area, the manhole closest to E3312 was assigned the number 3000, the next manhole was assigned the number 3010, the next manhole was assigned the number 3020, and so forth. Increments of 10 were used to allow additional manholes to be inserted into the inventory system and still remain in order according to location. On the manhole inventory chart, this identification number is contained in the MANHOLE ID column. The NODE or SECTION column indicates the node number for manholes that are located at a node, and the section number for manholes that are located along a pipe section (not at a node). The LOCATION column includes more specific location information.

Table B1. Pipe section identification spreadsheet for APG/EA.

Section ID	Map Sheet	From Location	To Location	OH/ UG	STM DIAM	R DIAM	Length	MAT Code	Year Inst	Summer
3160-3165	21Q	BLD E3160	BLD T3165	OH	2		210	AG	1940	ON
31A-3100	22P	NODE 31A	BLD E3100	OH	6	3	280	AG	1940	ON
31B-3148	22Q	NODE 31B	BLD T3148	OH	6		90	AG	1940	ON
3222-3242	23P	BLD E3222	BLD E3242	OH	1.5	NO	150	AG	1940	ON
32A-3265	23P	NODE 32A	BLD T3265	OH	3		50	AG	1940	ON
32B-3226	23P	NODE 32B	BLD E3226	OH	4	1.5	310	AG	1940	ON
32C-3266	23P	NODE 32C	BLD E3266	OH	1.25		40	AG	1940	ON
32D-3266	23P	NODE 32D	BLD E3266	OH	1.5		120	AG	1940	ON
32E-32L	23P	NODE 32E	NODE 32L	OH	2		20	AG	1940	ON
32F-3222	23P	NODE 32F	BLD E3222	OH	3		40	AG	1940	ON
32G-3244	23P	NODE 32G	BLD E3244	OH	3		440	AG	1940	ON
32H-3228	23P	NODE 32H	BLD E3228	OH	2		10	AG	1940	ON
32I-3230	23P	NODE 32I	BLD E3230	OH	2		10	AG	1940	ON
32J-3232	23P	NODE 32J	BLD E3232	OH	2		10	AG	1940	ON
32K-3234	23P	NODE 32K	BLD E3234	OH	2		10	AG	1940	ON
32L-3222	23P	NODE 32L	BLD E3222	OH	2		60	AG	1940	ON
32L-32K	23P	NODE 32L	NODE 32K	OH	3		450	AG	1940	ON
3312-30A	22-23P,21-24Q	BDG E3312	NODE 30A	OH	6	4	3350	AG	1940	ON
3312-3160	22-23P,21-24Q	BLD E3312	BLD E3160	OH	6	3	3945	AG	1940	ON
3312-3330	24Q	BDG E3312	BDG E3330	OH	8		100	AG	1940	ON
3312-33A	24P	BLD E3312	NODE 33A	OH	5	3	590	AG	1940	ON
3312-3516	24Q,25Q	BDG E3312	BDG E3516	OH	5	2	280	AG	1940	ON

Table B1. (Cont'd).

Section ID	Map Sheet	From Location	To Location	OH/ UG	STM DIAM	R DIAM	Length	MAT Code	Year Inst	Summer
3312-37A	24P-S	BDG E3312	NODE 37A	OH	8	4	1930	AG	1940	ON
3326-3325	24P	BLD E3326	BLD E3325	OH	1.5	NO	120	AG	1940	ON
3329-3326	24P	BLD E3329	BLD E3326	OH	1.25	NO	220	AG	1940	ON
33A-3320	24P	NODE 33A	BLD E3320	OH	2.5	1.5	20	AG	1940	ON
33A-3331	24P	NODE 33A	BLD E3331	OH	4	2	160	AG	1940	ON
33AA-3346	24P	NODE 33AA	BDG E3346	OH	1	NO	100	AG	1940	ON
33B-3360	24Q	NODE 33B	BDG T3360	OH	1		10	AG	1940	ON
33C-3370	24Q	NODE 33C	BDG T3370	OH	1		80	AG	1940	ON
33D-3348	24Q	NODE 33D	BDG E3348	OH	1.5		20	AG	1940	ON
33E-3334	24Q	NODE 33E	BLD E3334	OH	3		150	AG	1940	ON
33F-3329	24Q,24P	NODE 33F	BLD E3329	OH	1	NO	90	AG	1940	ON
3514-3525	25Q	BDG E3514	BDG E3525	OH	2	NO	350	AG	1940	ON
3516-35B	25Q	BDG E3516	NODE 35B	OH	2.5	1.25	140	AG	1940	ON
3516-35H	25Q	BDG E3516	NODE 35H	OH	3	NO	360	AG	1940	ON
3560-3566	25R	BLD E3560	BLD E3566	OH	1		40	AG	1940	ON
3563-3567	25R	BDG E3563	BDG E3567	OH	1		30	AG	1940	ON
35A-3510	25Q	NODE 35A	BDG E3510	OH	3	2	420	AG	1940	ON
35B-3500	25P	NODE 35B	BDG E3500	OH	2	1.25	30	AG	1940	ON
35B-3514	25Q	NODE 35B	BDG E3514	OH	2		60	AG	1940	ON
35C-3517	25Q	NODE 35C	BDG T3517	OH	1.5		10	AG	1940	ON
35D-3518	25Q	NODE 35D	BDG T3518	OH	1.5		10	AG	1940	ON
35E-3519	25Q	NODE 35E	BDG T3519	OH	1.5		10	AG	1940	ON
35F-3521	25Q	NODE 35F	BDG T3521	OH	1.5		10	AG	1940	ON
35G-3523	25Q	NODE 35G	BDG T3523	OH	1.5		10	AG	1940	ON

Table B1. (Cont'd).

Section ID	Map Sheet	From Location	To Location	OH/ UG	STM DIAM	R DIAM	Length	MAT Code	Year Inst	Summer
35GA-3540	25Q	NODE 35GA	BDG E3540	OH	1.5		10	AG	1940	ON
35H-3550	25Q	NODE 35H	BLD E3550	OH	3		100	AG	1940	ON
35H-35J	25Q	NODE 35H	NODE 35J	OH	2	NO	160	AG	1940	ON
35I-3552	25Q	NODE 35I	BLD E3552	OH	2		140	AG	1940	ON
35J-3542	25Q	NODE 35J	BDG E3542	OH	1.5	NO	120	AG	1940	ON
35J-3546	25Q	NODE 35J	BDG E3546	OH	1.25	NO	140	AG	1940	ON
35K-35KA	25R	NODE 35K	NODE 35KA	OH	8	4	150	AG	1990	ON
35K-35M	25R	NODE 35K	NODE 35M	OH	4	2	180	AG	1940	ON
35KA-3549	25R	NODE 35KA	BDG E3549	OH	8	4	400	AG	1989	ON
35KA-3570	25R	NODE 35KA	BDG E3570	OH	4	2	40	AG	1940	ON
35L-3563	25R	NODE 35L	BDG E3563	OH	3		30	AG	1940	ON
35M-3560	25R	NODE 35M	BDG E3560	OH	3		80	AG	1940	ON
36A-3615	24Q	NODE 36A	BDG 3615	OH	0.75		160	AG	1940	ON
36A-3622	24Q	NODE 36A	BDG E3622	OH	1		90	AG	1940	ON
36B-35K	24R	NODE 36B	NODE 35K	OH	8	4	380	AG	1989	ON
3726-3724	24S	BDG E3726	BDG E3724	OH	3		130	AG	1940	ON
3726-3728	24S	BDG E3726	BDG E3728	OH	2		140	AG	1940	ON
37A-3580	24S,25S	NODE 37A	BDG E3580	OH	3	2	620	AG	1940	ON
37A-3726	24S	NODE 37A	BDG E3726	OH	4	2	220	AG	1940	ON
30A-3081	21Q	NODE 30A	BDG 3081	UG	6	4	250	RW	1940	ON
3220-3224	23P	BLD E3220	BLD E3224	UG	3	NONE	190	T	1940	ON
3224-3226	23P	BLD E3224	BLD E3226	UG	2	1	50	T	1940	ON
32E-3220	23P	NODE 32E	BLD E3220	UG	6	4	430	T	1940	ON
37A-3835	24S	NODE 37A	BDG E3835	UG	6	4	1200	RW	1990	ON

Table B1. (Cont'd).

Section ID	Map Sheet	From Location	To Location	OH/ UG	STM DIAM	R DIAM	Length	MAT Code	Year Inst	Summer
4225-42M	24O	BLD 4225	NODE 42M	OH	4	2	130	AG	1992	ON
4160-4162	400	BLD E4160	BLD E4162	UG	2	1.5	50	T	1940	ON
4160-44A	24M	BLD E4160	NODE 44A	UG	8	6	350	T	1940	ON
4160-4810	24L	BLD E4160	BLD E4810	UG	2	1.5	320	S-PR	1991	ON
4225-4230	24N	BLD E4225	BLD E4230	UG	3	1.5	280	T	1962	ON
42A-4221	24N	NODE 42A	BLD E4221	UG	3?	?	700	S-PR	1987?	ON
42A-4229	24N	NODE 42A	BLD E4229	UG	3	3?	500	S-PR	1987?	ON
42B-4227	24N	NODE 42B	BLD E4227	UG	3?	?	20	S-PR	1987?	ON
42C-4228	24N	NODE 42C	BLD E4228	UG	3?	?	20	S-PR	1987?	ON
42D-4224	24N	NODE 42D	BLD E4224	UG	3?	?	40	S-PR	1987?	ON
42E-4223	24N	NODE 42E	BLD E4223	UG	3?	?	180	S-PR	1987?	ON
42F-4222	24N	NODE 42F	BLD E4222	UG	3?	?	40	S-PR	1987?	ON
42M-4210	400	NODE 42M	BLD E4210	UG	2	?	400	S-PR	1992	ON
42M-42N	24O,24N	NODE 42M	NODE 42N	UG	4	2	480	S-PR	1992	ON
42N-4215	24N	NODE 42N	BLD E4215	UG	3	1.5	160	S-PR	1992	ON
42N-4220	24N	NODE 42N	BLD E4220	UG	2	1	80	S-PR	1992	ON
44A-44B	24M	NODE 44A	NODE 44B	UG	4	2	130	T	1940	ON
44A-44C	24M	NODE 44A	NODE 44C	UG	6	6-4	480	T	1940	ON
44A-44F	24M	NODE 44A	NODE 44F	UG	8	3	160	T	1940	ON
44B-4465	24M	NODE 44B	BLD E4465	UG	2.5	2	40	T	1940	ON
44B-4470	24M	NODE 44B	BLD E4470	UG	2.5	2	80	T	1940	ON
44C-4430	24M	NODE 44C	BLD E4430	UG	2.5	NONE	80	T	1940	ON
44C-44D	24M	NODE 44C	NODE 44D	UG	4	4	100	T	1940	ON
44D-4140	24M,23M	NODE 44D	BLD E4140	UG	4	1.5	380	S-PR	1991	ON

Table B1. (Cont'd).

Section ID	Map Sheet	From Location	To Location	OH/ UG	STM DIAM	R DIAM	Length	MAT Code	Year Inst	Summer
44D-44E	24M	NODE 44D	NODE 44E	UG	4	3	110	T	1940	ON
44E-4405	24M	NODE 44E	BLD E4405	UG	2.5	2	40	T	1940	ON
44E-4410	24M	NODE 44E	BLD E4410	UG	2.5	2	80	T	1940	ON
44F-44G	24M	NODE 44F	NODE 44G	UG	6	3	180	T	1940	ON
44F-4620	24M	NODE 44F	BLD E4620	UG	4	2.5-1.5	500	S-PR	1991	ON
44G-44H	24M	NODE 44G	NODE 44H	UG	4	3	140	T	1940	ON
44G-44IA	24M	NODE 44G	NODE 44IA	UG	6	3	240	T	1940	ON
44H-4475	24M	NODE 44H	BLD E4475	UG	2.5	2	60	T	1940	ON
44H-4480	24M	NODE 44H	BLD E4480	UG	2.5	3	30	T	1940	ON
44I-4455	24M	NODE 44I	BLD E4455	UG	2.5	2	80	T	1940	ON
44I-4460	24M	NODE 44I	BLD E4460	UG	2.5	2	40	T	1940	ON
44IA-44J	24M	NODE 44IA	NODE 44J	UG	5	3.5	250	T	1940	ON
44J-4435	24M	NODE 44J	BLD E4435	UG	2.5	2	70	T	1940	ON
44J-4440	24M	NODE 44J	BLD E4440	UG	2.5	2	40	T	1940	ON
44J-44K	24M	NODE 44J	NODE 44K	UG	4	3	80	T	1940	ON
44K-4420	24M	NODE 44K	BLD E4420	UG	2.5	2	120	T	1940	ON
44K-44L	24M	NODE 44K	NODE 44L	UG	3.5	2	40	T	1940	ON
44L-42A	24M	NODE 42L	NODE 42A	UG	3	2	400	T	1940	ON
44L-44M	24M	NODE 44L	NODE 44M	UG	3	2	40	T	1940	ON
44M-4415	24M	NODE 44M	BLD E4415	UG	2.5	2	80	T	1940	ON
5126-5125	20N	BLD E5126	BLD E5125	OH	1.5		50	AG	1940	
5126-51E	20M	BLD 5126	NODE 51E	OH	3	NO	370	AG	1940	ON
5126-51J	19N	BLD E5126	NODE 51J	OH	6		80	AG	1940	OFF

Table B1. (Cont'd).

Section ID	Map Sheet	From Location	To Location	OH/ UG	STM DIAM	R DIAM	Length	MAT Code	Year Inst	Summer
51E-5135	20M	NODE 51E	BLD E5135	OH	1	NO	60	AG	1940	
51E-5137	20M	NODE 51E	BLD E5137	OH	1?	NO	20	AG	1940	
51E-51G	20M	NODE 51E	NODE 51G	OH	1.5	NO	180	AG	1940	ON
51F-5232	20M	NODE 51F	BLD E5232	OH	1	NO	20	AG	1940	
51G-5234	20M	NODE 51G	BLD E5234	OH	1	NO	20	AG	1940	
51J-51K	19N	NODE 51J	NODE 51K	OH	3		130	AG	1940	OFF
51K-5175	19N	NODE 51K	BLD E5175	OH	1.5		20	AG	1940	OFF
51K-5179	19M,19N	NODE 51K	BLD E5179	OH	3		260	AG	1940	OFF
51KA-5173	19N	NODE 51KA	BLD E5173	OH	1.5		10	AG	1940	OFF
51L-5101	19M	NODE 51L	BLD E5101	OH	3	YES	480	AG	1940	ON
51L-51LA	19M	NODE 51L	NODE 51LA	OH	3	YES	340	AG	1940	ON
51L-51R	18L-M,19M	NODE 51L	NODE 51R	OH	10	YES	960	T	1940	SOME
51M-5146	19M	NODE 51M	BLD E5146	OH	2	YES	60	AG	1940	ON
51O-5180	18M	NODE 51O	BLD E5180	OH	1	YES	120	AG	1940	ON
51R-5188	18L	NODE 51R	BLD E5188	OH	4	YES	260	AG	1940	SOME
52B-5307	20L	NODE 52B	BLD E5307	OH	2		560	AG	1940	OFF
54A-54CA	21L	NODE 54A	NODE 54CA	OH	4		585	AG	1940	OFF
54B-5425	21L	NODE 54B	BLD E5425	OH	1.5		20	AG	1940	OFF
54B-5427	21L	NODE 54B	BLD E5427	OH	2		180	AG	1940	OFF
54C-5452	21L	NODE 54C	BLD E5452	OH	2		20	AG	1940	OFF
54CB-5352	20L	NODE 54CB	BLD E5352	OH	4		625	AG	1940	OFF
55A-54B	21K,21L	NODE 55A	NODE 54B	OH	4		1530	AG	1940	OFF
55A-5590	21K	NODE 55A	BLD E5590	OH	4		160	AG	1940	OFF
5695-5697	17J	BLD E5695	BLD E5697	OH	2		560	AG	1940	OFF

Table B1. (Cont'd).

Section ID	Map Sheet	From Location	To Location	OH/ UG	STM DIAM	R DIAM	Length	MAT Code	Year Inst	Summer
56C-56D	19L,18L	NODE 56C	NODE 56D	OH	8	YES	780	AG,FGR	1940	OFF
56D-56E	18L,18K	NODE 56D	NODE 56E	OH	4	NO	400	AG	1940	OFF
56D-57A	18L,17L	NODE 56D	NODE 57A	OH	6	YES	440	AG,FGR	1940	OFF
56E-5648	17J-K,18K	NODE 56E	BLD E5648	OH	2	NO	360	AG	1992	OFF
56FA-56K	18J-K,19K	NODE 56FA	NODE 56K	OH	8		1445	AG	1940	OFF
56FB-56FA	20L	NODE 56FB	NODE 56FA	OH	8		600	AG	1940	OFF
56K-5685	17J	NODE 56K	BLD E5685	OH	4		40	AG	1940	OFF
56K-5695	17J	NODE 56K	BLD E5695	OH	6		290	AG	1940	
57A-5703	17L	NODE 57A	BLD E5703	OH	3	YES	320	AG,FGR	1940	OFF
57A-5707	17L	NODE 57A	BLD E5707	OH	3	YES	10	AG	1940	OFF
55A-5560	21K	NODE 55A	BLD E5560	OH?	1.5		20	?	1940	OFF
5126-51A	20N	BLD E5126	NODE 51A	UG	8	NO	620	S-PR	NEW	ON
5126-51L	19M	BLD E5126	NODE 51L	UG	10	YES	620	T	1940	SOME
5126-52C	20M	BLD E5126	NODE 52C	UG	8	YES	1960	T	1940	OFF
51A-5100	20N	NODE 51A	BLD E5100	UG	4	NO	410	S-PR	NEW	ON
51A-51D	20N	NODE 51A	NODE 51D	UG	4	NO	570	S-PR	NEW	ON
51B-5116	20N	NODE 51B	BLD E5116	UG	1	NO	100	S-PR	NEW	ON
51C-5106	20N	NODE 51C	BLD 5106	UG	2	NO	130	S-PR	NEW	ON
51D-5103	20N	NODE 51D	BLD E5103	UG	2	NO	260	S-PR	NEW	ON
51G-5236	20M,21M	NODE 51G	BLD E5236	UG	1.5	NO	240	T	1940	ON
51H-51I	20M	NODE 51H	NODE 51I	UG	2		160	T	1940	
51HA-5244	20M	NODE 51HA	BLD E5244	UG	1.5		20	T	1940	
51I-5140	20M	NODE 51I	BLD 5140	UG	1.5?		10	T	1940	
51I-5141	20M,19M	NODE 51I	BLD E5141	UG	1.5		160	T	1940	

Table B1. (Cont'd).

Section ID	Map Sheet	From Location	To Location	OH/ UG	STM DIAM	R DIAM	Length	MAT Code	Year Inst	Summer
51J-5165	19N	NODE 51J	BLD E5165	UG	4		610	T	1940	OFF
51LA-51P	18M,19M	NODE 51LA	NODE 51P	UG	3	YES	540	S-WY	1980	ON
51N-5181	18M	NODE 51N	BLD E5181	UG	1?	?	10	?		ON
51O-5183	18M	NODE 51O	BLD E5183	UG	3	YES	60	?		ON
51P-5026	18M	NODE 51P	BLD E5026	UG	1.5	YES	130	S-WY	1980	ON
51P-5027	18M	NODE 51P	BLD E5027	UG	1.5?	YES	20	S-WY	1980	ON
51R-56A	18L,19L,20L	NODE 51R	NODE 56A	UG	14	NO	560	T	1940	OFF
5265-5266	21M	BLD E5265	BLD E5266	UG	1.25		40	T	1940	
52A-5246	20M	NODE 52A	BLD E5246	UG	3		60	T	1940	
52C-5265	21L,21M	NODE 52C	BLD 5265	UG	4	NO	280	T	1940	OFF
52C-5422	21L	NODE 52C	BLD E5422	UG	2	NO	240	T	1940	OFF
5352-5354	20L	BLD E5352	BLD E5354	UG	3	YES	100	T,FGR	1940	OFF
5360-5357	20L	BLD E5360	BLD E5357	UG	2		80	T	1940	
54CA-54CB	21L	NODE 54CA	NODE 54CB	UG	4		100	T	1940	OFF
54D-5360	20L	NODE 54D	BLD E5360	UG	3		100	T	1940	OFF
56A-5604	19L	NODE 56A	BLD E5604	UG	4	YES	40	T,FGR	1940	SOME
56A-56B	19L	NODE 56A	NODE 56B	UG	3	YES	290	T,FGR	1940	SOME
56A-56F	19L	NODE 56A	NODE 56F	UG	16	6	870	T	1940	OFF
56B-5609	19L	NODE 56B	BLD E5609	UG	2	YES	50	T,FGR	1940	?
56F-56FC	19K,20L	NODE 56F	NODE 56FC	UG	8		290	S-PR	1992	OFF
56F-56G	20L	NODE 56F	NODE 56G	UG	10	NO	220	?	NEW	OFF
56FC-56FB	19K	NODE 56FC	NODE 56FB	UG	8		325	S-WY	1980	OFF
56G-56J	20L	NODE 56G	NODE 56J	UG	10	NO	500	T	1940	OFF
56I-5365	20L	NODE 56I	BLD E5365	UG	2.5	NO	50	T	1940	OFF

Table R1 (Cont'd).

Section ID	Map Sheet	From Location	To Location	OH/ UG	STM DIAM	R DIAM	Length	MAT Code	Year Inst	Summer
56J-52B	20L	NODE 56J	NODE 52B	UG	10		900	T	1940	OFF
56J-55A	21K,21L	NODE 56J	NODE 55A	AG	4	NO	720	AG	NEW	OFF

Table B2. Manhole identification spreadsheet for APG/EA.

Manhole ID	Node or Section	Location
3000	32E-E3220	NEAR NODE 32E
3010	32E-E3220	NEAR E3222
3020	32E-E3220	NEAR E3220
4000	E4160-E4810	CLOSEST TO E4160
4010	E4160-E4810	BETWEEN E4160 & E4810
4020	E4160-E4810	CLOSEST TO E4810
4030	E4160-44A	BETWEEN E4160 & NODE 44A
4040	NODE 44A	AT NODE 44A
4050	NODE 44B	AT NODE 44B
4060	44A-44C	NEAR BLD E4445
4070	44A-44C	NEAR LEACH RD.
4080	44A-44C	NEAR BLD 4430
4090	NODE 44C	AT NODE 44C
4100	NODE 44D	AT NODE 44D
4110	44D-E4140	NEAR E4140
4120	NODE 44E	AT NODE 44E
4130	NODE 44F	AT NODE 44F
4140	44A-E4620	BETWEEN BLD E4470 & E4475
4150	44A-E4620	NEAR BLD E4620
4160	44F-44G	NEAR BLD E4455
4170	NODE 44G	AT NODE 44G
4180	NODE 44H	AT NODE 44H
4190	NODE 44I	AT NODE 44I
4200	NODE 44IA	AT NODE 44IA
4210	44IA-44J	NEAR BLD E4435
4220	NODE 44J	AT NODE 44J
4230	NODE 44K	AT NODE 44K
4240	NODE 44M	AT NODE 44M
4250	44L-42A	BETWEEN E4415 & E4420
4260	NODE 42A	AT NODE 42A
4270	NODE 42D	AT NODE 42D
4280	NODE 42E	AT NODE 42E
4290	42E-4223	NEAR BLD 4223

Table B2. (Cont'd).

Manhole ID	Node or Section	Location
4300	NODE 42F	AT NODE 42F
4310	42A-E4221	NEAR BLD E4221
5000	E5126-52C	1ST MH AFTER BLD E5126
5010	E5126-52C	NEAR BLD 5238
5020	NODE 51H	AT NODE 51H
5030	NODE 51HA	AT NODE 51HA
5040	E5126-52C	NEAR BLD 5244
5050	NODE 52A	AT NODE 52A
5060	NODE 52B	AT NODE 52B
5070	E5126-52C	ABOUT 200 FT FROM MH 5060
5080	E5126-52C	ABOUT 50 FT FROM MH 5070
5090	NODE 52C	AT NODE 52C
5100	NODE 54D	AT NODE 54D
5110	54A-E5352	BETW BLD E5352 & E5360
5120	E5352	AT BLD E5352
5135	E5380	AT BLD E5380
5130	NODE 56J	AT NODE 56J
5140	NODE 56I	AT NODE 56I
5150	NODE 56H	AT NODE 56H
5160	NODE 56G	AT NODE 56G
5170	REMOVED	
5180	56F-56FA	NEAR BLD 5654
5190	NODE 56FA	AT NODE 56FA
5200	56A-56F	FLEMING & ALLEY
5210	56A-56F	NEAR BLD E5616
5220	NODE 56C	AT NODE 56C
5230	NODE 56A	AT NODE 56A
5240	56A-56B	NEAR BLD E5604
5250	NODE 56B	AT NODE 56B
5260	NODE 51R	AT NODE 51R
5270	NODE 51L	AT NODE 51L
5275	NODE 51M	AT NODE 51M, NEAR BLD E5101
5280	51L-51P	NEAR W.E.P. LINE
5290	NODE 51O	AT NODE 51O

Table B2. (Cont'd).

Manhole ID	Node or Section	Location
5300	51L-51P	NEAR BLACKHAWK RD
5310	E5126-51A	NEAR BLD E5126
5320	E5126-51A	BETWEEN MH 5310 & MH 5330
5330	NODE 51A	AT NODE 51A
5340	NODE 51C	AT NODE 51C
5350	51A-51D	NEAR BLD E5106
5360	51D-E5103	NEAR BLD E5103

Appendix C: 1993 Condition Survey Results for Edgewood Area

Aboveground System: Pipe Section Condition Ratings

Tables C1 and C2 contain pipe section condition ratings for the portions of the aboveground system that were surveyed. In the 3000 area, approximately 16,900 linear feet, or 83 percent of the aboveground system was surveyed. In the 5000 area, approximately 7,600 linear feet, or 58 percent of the aboveground system was surveyed. The 4000 area contains a negligible amount of aboveground piping. The pipe sections are listed in alphanumeric order. Each section that was inspected is given a rating according to the following scale:

G = Good condition: no deficiencies noted; no repairs needed
F = Fair condition: minor deficiencies (such as missing insulation) noted; minor repairs needed
P = Poor condition: major deficiencies (such as leaks or severe steaming) were noted. Replacement should be considered.

Pipe Section Inspection Comments

The pipe sections that were inspected are listed below in alphanumeric order. Most of these sections are aboveground. The comments and deficiencies noted during the walk-through inspection appear under each pipe section identification. Inspections were conducted according to the procedures described in Chapter 3 of the main text. In addition, sections that have been proposed for replacement by APG have been noted.

SECTION 31B-3148: There is a small leak near T3148 next to the building.

SECTION 3222-3242: There is a flange leak near Bldg E3222. There is a small amount of missing insulation. The rest of the line looks good.

SECTION 32A-3265: There is a slight valve leak. The steam and condensate lines are totally uninsulated.

SECTION 32B-3226: The metal poles need recoating. There is missing insulation at elbows and on some lengths of pipe, especially near the expansion loop and on the takeoff to Bldg E3226.

SECTION 32C-3266: There is missing insulation at elbow.

SECTION 32F-3222: There is no insulation. There is an exposed valve that is steaming slightly.

SECTION 3312-30A: There are some sections of missing insulation along this line. An uninsulated section about 15' long was noted near T3151. At the transfer station where lines are tied together, there is missing insulation, and valves are exposed and uninsulated. Eventually, a galvanized steel ladder should be installed to replace the existing wooden one at the transfer station.

SECTION 3312-3160: This section is proposed for replacement with 10 in. steam, 6 in. return. New R line has already been installed from node 32E to Bldg E3148. The new line is in good condition. However, the old line is in poor condition and is undersized. There is missing insulation on several sections of the steam & return lines. The tree growing between the lines near fence adjacent to transfer station should be removed. There is a leaning support pole also near this fence. The expansion loop near E3234 is tilted such that it would be impossible to completely drain it. There is a leaky valve at node 32G and condensate is dripping onto the other pipes. There is another leaky valve near T3151 where the two lines come back together. Just past node 31B, there is a support that appears to be missing pipe hangers and the pipes are resting directly on the cross members of the support.

SECTION 3312-33A: Steel poles need to be recoated. Some elbows have missing insulation.

SECTION 3312-3516: Both steam and condensate lines are missing insulation on some elbows.

SECTION 3312-37A: Proposed for replacement in Year 1 with 10" steam, 6" return. Condensate line is in EXTREMELY poor condition. There were severe condensate leaks and steaming near Bldg E3370. Most leaks were on the top area of pipe. Insulation was badly deteriorated and wet in some areas. Insulation was removed from lines in several locations. Visual inspection revealed that lines were corroding from the outside, most likely due to wet insulation. Steam line was in fair condition, although there was missing insulation in some places, especially at the elbows. There was also missing insulation on return line. Corrosion problems on metal poles. Also,

some cable supports are badly corroded and others are slack. Trees around and between lines should be removed. There is a leaky valve on the return line near node 37A. This valve is not protected from the weather. There is a leaky flange near the junction with steam line 36B-35K. Some of the support poles were leaning. The abandoned, leaning structure near the lines at 3615 should be removed or relocated. Missing insulation was noted near Bldg T3370.

SECTION 33A-3331: Check insulation on section that crosses the road. Steel poles need recoating.

SECTION 33C-3370: There is missing insulation near the junction with the 8 in. main.

SECTION 33E-3334: There is insulation missing at the elbows.

SECTION 3516-35B: Top cross-members of support poles are corroded. A steam trap was blowing in front of Bldg E3516.

SECTION 35A-3510: Steam line is missing insulation on some elbows. The return line is about 2 years old and is in good condition.

SECTION 35B-3500: There is insulation missing from the elbow and insulation missing from about 5' of pipe.

SECTION 35B-3514: There is missing insulation at the elbows.

SECTION 35H-3550: There is no condensate return line. Insulation is missing from elbow near E3550. Support poles need recoating.

SECTION 35H-35J: There is a small amount of insulation missing from elbow. Support poles need recoating.

SECTION 35I-3552: There is a small amount of insulation missing from elbow. Also insulation is missing near E3552. Support poles need recoating.

SECTION 35K-35M: There is a small amount of missing insulation.

SECTION 35KA-3570: There is missing insulation on a section of the line.

SECTION 36B-35K: At one location, the pipes do not rest on the support rollers. Rollers should be adjusted upward so the pipes are supported.

SECTION 3726-3724: This line has been proposed for replacement with same size line overhead.

SECTION 3726-3728: This line has been proposed for replacement with same size line overhead.

SECTION 37A-3580: Metal poles are corroded and should be sandblasted and recoated.

SECTION 37A-3726: This line has been proposed for replacement with same size line overhead. Remove the tree growing between the steam and return lines. There is a small amount of missing insulation.

SECTION 30A-3081: If these are watershed caps where pipes enter the ground, the conduit of the underground line is not pressure-testable.

SECTION 37A-3835: This is an underground line. There was about 2 in. water and steaming in manhole near Bldg 3724. There was also water in the CP test station. Problems reported by O&M personnel with drainage of condensate. Suspect some wet insulation. O&M had to drain condensate line. An excavation was done here, but couldn't locate line. Ground was steaming at soil sample location. No external corrosion problems reported.

SECTION 51L-51R: There was severe steaming at 51R. There is a bent support pole near 5185. There is steaming water in the stream downhill from the manhole.

SECTION 52B-5307: Insulation is missing at the elbows.

SECTION 54A-54CA: O&M says that this line has no function, is in terrible condition, and should be removed. Asbestos is present.

SECTION 54CB-5362: O&M says that this line has no function, is in terrible condition, and should be removed. Asbestos is present.

SECTION 5695-5697: There is an area of steaming near Bldg E5697.

SECTION 56C-56D: The steam line is in fair to poor condition. It is covered with asbestos insulation.

SECTION 56D-56E: There is a small amount of insulation missing on the elbows on the section that goes across the road.

SECTION 56E-5648: There was steaming at the Bldg near node 56E.

SECTION 56FA-56K: Insulation is missing from the elbows on the steam line. The condensate line is out of service and is in failed condition. The pipe supports are somewhat deteriorated and have experienced surface corrosion over 50 to 100% of the surface. In some areas, the lines are overgrown with vegetation (trees, weeds, and grass).

SECTION 56K-5685: Insulation is missing on sections of the line going across the street.

SECTION 5126-51A: This line is underground and has been proposed for replacement with the same size during Year 1. A condensate line is planned. There was dead grass above the line and evidence of poor pipe condition in the manholes inspected.

SECTION 51A-5100: This section is proposed for replacement of steam line and addition of new condensate line.

SECTION 51A-51D: This section is proposed for replacement of steam line and addition of new condensate line.

SECTION 51B-5116: This section is proposed for replacement of steam line and addition of new condensate line.

SECTION 51C-5106: This section is proposed for replacement of steam line and addition of new condensate line.

SECTION 51D-5103: This section is proposed for replacement of steam line and addition of new condensate line.

SECTION 5360-5357: There was steaming near Bldg E5357.

SECTION 56A-5604: The manhole near 5604 was steaming. This indicates the presence of water in the manhole and high heat loss.

SECTION 56A-56F: O & M says this line needs to be rerouted because Bldg E5626 is being torn down; needs to hook into line next to 5604. Steam was coming from the vaults. There was a blowing steam trap near Bldg E5625.

SECTION 56F-56G: The vent between 56F and 56G was steaming.

Underground System: Manhole Inspection Comments

The manholes that were inspected are listed below in numeric order. The comments and deficiencies that were noted during the field inspection appear next to the manhole identification. Note that where severe manhole deficiencies are indicated (particularly steaming or water intrusion), it is likely that the corresponding piping is also deteriorated.

MANHOLE 4040: Dimensions are 12' x 12' x 9' deep. This is a raised-top manhole with steel plate covers.
PROBLEMS: There is no sump pump. Water marks on the walls indicate previous flooding at the 3 foot level. There is considerable debris in the manhole. The hole in the wall from old system penetration should be sealed and waterproofed. Cracks in manhole walls need to be repaired. Repair the valve packing leak. Install new screens at the manhole vent openings. There was no steaming of the conduit vents.

MANHOLE 4130: Manhole was dry at the time of the survey.
PROBLEMS: Valve packing leak should be repaired. Install manhole access ladder. Pipe supports and structural beams are badly corroded. Seal manhole wall cracks and openings. Fifteen feet of piping requires insulation. One of the conduit casings has completely corroded through. There was slight vapor from steam line conduit casing. There is no sump pump.

MANHOLE 4170: Dimensions are 9' x 9' x 9' deep. Manhole was dry at the time of the survey.
PROBLEMS: Valve packing leak should be repaired. Install manhole access ladder. Pipe supports and structural beams are badly corroded. Seal manhole cracks and wall openings. Insulation is missing from piping. There is no sump pump.

MANHOLE 4190: PROBLEMS: Repair valve packing leak. All internal piping requires insulation. Slight vapor was observed at one of the conduit vents. Slight leak was observed in condensate return piping. There were some wall cracks and general deterioration. There is no sump pump.

MANHOLE 4220: Dimensions are 7' x 6' x 7' deep.
PROBLEMS: There was a slight leak in the condensate line. There were two valve packing leaks. Slight vapor was coming from steam conduit vent. There were several large cracks in the manhole walls. There is no sump pump.

MANHOLE 4230: Dimensions are 6' x 8' x 7' deep.
PROBLEMS: Steam and water were coming out of the tile conduit run to the building. Internal support steel channels are severely corroded. Valve packing leak should be repaired. The vent on one of the conduit casings is disconnected. The manhole floor is wet but not flooded. There is no sump pump.

MANHOLE 5000: Distribution conduit is full round tile.
PROBLEMS: Manhole walls are cracked and spalling. There is no access ladder. Roller guides on each side of the manhole are broken. Prefabricated top for manhole is not set properly on manhole walls. New hinges should be provided for access hatch. There is no sump pump.

MANHOLE 5010: Dimensions are 4' x 7' x 5' deep. Conduit is full round tile.
PROBLEMS: There is no access ladder. The manhole is outlined by dead grass indicating high heat loss. There is considerable corrosion on internal piping. There is no sump pump.

MANHOLE 5020: Dimensions are 4' x 5' x 8' deep.
PROBLEMS: Dead grass outlines the conduit run from Manhole 5010, indicating high heat loss. There is no insulation on the 8 in. steam line or the 2 in. take-off. There is no sump pump.

MANHOLE 5030:
PROBLEMS: Dead grass outlines conduit path between manholes, indicating high heat loss. The 8" steam line and 2" take-off are not insulated. Two inch line extends to outside of building and is exposed and uninsulated for a distance of 25 ft. Exposed pipe surface temperature is 260 °F. There is no sump pump. There is a heavy mud deposit on the manhole floor.

MANHOLE 5055: Dimensions are 5' x 5' x 6' deep.
PROBLEMS: Seven feet of 8" steam line are not insulated. There is no sump pump. Condensate is being wasted through a 1" line; the failed steam trap should be replaced.

MANHOLE 5060: Dimensions are 6' x 6' x 9' deep. Manhole has solid concrete top with steel plate access hatch. This is a transition manhole from the underground to the aboveground system.
PROBLEMS: Anchor in manhole is broken. There is no sump pump.

MANHOLE 5070: Dimensions are 5' x 4' x 9' deep.
PROBLEMS: Five feet of 8" steam line are uninsulated. There is no sump pump. The 4 in. take-off and the underside of steel plate tops are badly corroded.

MANHOLE 5080: Transition manhole from aboveground to underground system.
PROBLEMS: Manhole is filled with mud covering the heat-carrying pipe. There is no sump pump.

MANHOLE 5090: PROBLEMS: Dry grass outlines the route of the conduit to manhole, indicating high heat loss. Insulation in the tile conduit has fallen off for a distance of about 5 ft from manhole wall. Most of the internal piping is uninsulated. Surface temperature of the steam line is 330 °F and of the condensate line is 170 °F. The 8" steel channel holding the heavy slip-type expansion joint is badly corroded and weakened. Crack in the manhole wall may allow groundwater infiltration. There is no sump pump.

MANHOLE 5095: Dimensions are 4' x 6' x 5' deep. Extends from underground to aboveground at building.
PROBLEMS: There is no insulation on the steam line. The steam line is corroded. The anchor support beam is corroded. There is no sump pump.

MANHOLE 5100: PROBLEMS: Insulation is missing from pipes in manhole. Manhole internals are very deteriorated and are in poor condition. There is no sump pump.

MANHOLE 5130: Dimensions are 8' x 10' x 9' deep. This is a transition manhole from underground to aboveground system. This is a raised-top manhole.
PROBLEMS: Failed steam trap in manhole should be replaced. There is no sump pump.

MANHOLE 5135: This manhole was steaming during the drive-by inspection, indicating high heat loss and the presence of standing water in manhole.

MANHOLE 5160: This manhole was steaming during the drive-by inspection, indicating high heat loss and the presence of standing water in the manhole.

MANHOLE 5220: Contains 16" steam line (steel in terra cotta), and a fiberglass condensate return line.
PROBLEMS: There were 3 to 4 in. of water in the bottom of the manhole. The manhole was steaming. There is no sump pump.

MANHOLE 5230: This manhole was steaming during the drive-by inspection, indicating high heat loss and the presence of standing water in the manhole.

MANHOLE 5240: This manhole was steaming during the drive-by inspection, indicating high heat loss and the presence of standing water in the manhole.

MANHOLE 5310: This is a raised-top manhole with solid steel plate top. Contains 8 in. steam line but no condensate return. The steam line is encased in a 16 in. diameter full round tile. Manhole contains a bellows-type expansion joint. Steam line is in good condition.
PROBLEMS: Access ladder rungs are severely corroded and should be replaced. Insulation is needed for about 10 ft of piping. Screening on manhole wall vents should be replaced. Insulation in the tile conduit is missing for a distance of about 3 ft from the manhole wall. Temperature reading on the steam pipe surface is 330 °F. There is no sump pump.

MANHOLE 5320: Dimensions are 11' x 6' x 8' deep. Raised-top manhole with solid steel plate top. Manhole contains a bellows-type expansion joint.
PROBLEMS: Access ladder rungs are very corroded (up to 50 percent material loss on some) and should be replaced. Insulation is needed for about 10 feet of piping. Screening on manhole wall vents should be replaced. Insulation in the tile conduit is missing for a distance of about 3 feet from the manhole wall. Manhole braces need to be replaced. Pipe supports are in good condition. There is no sump pump.

MANHOLE 5330: This manhole is located in a restricted area and could not be inspected. Heavy steaming was noted from the manhole ventilation pipes, indicating serious problems.

MANHOLE 5340: Dimensions are 4' x 6' x 7' deep.
PROBLEMS: Manhole floor is covered with mud almost completely enveloping the piping. Piping has no insulation. There is no sump pump.

MANHOLE 5350: This is a solid top manhole with access hatch.
PROBLEMS: There is no insulation on the internal piping. There is no sump pump.

MANHOLE 5360: Dimensions are 5' x 8' x 6' deep. This is a solid top manhole with access hatch. PROBLEMS: There is no insulation on 6' of piping. There is no sump pump.

Table C1. Aboveground pipe section condition ratings for the 3000 Area.

Section ID	Length (ft)	Steam	Condensate
31A-3100	280	G	G
31B-3148	90	F	NONE
3222-3242	150	F	NONE
32A-3265	50	P	P
32B-3226	310	F	F
32C-3266	40	F	NONE
32F-3222	40	P	NONE
32G-3244	440	G	NONE
32L-3222	60	G	NONE
32L-32K	450	G	NONE
3312-30A	3350	F/G	F
3312-3160	3945	G/P	P*
3312-33A	590	F	F
3312-3516	280	F	F
3312-37A	1930	F	P
33A-3320	20	F	F
33A-3331	160	F	F
33AA-3346	100	G	NONE
33C-3370	80	F	NONE
33D-3348	20	G	G
33E-3334	150	G	NONE
33F-3329	90	G	G
3514-3525	350	G	G
3516-35B	140	G	G
3516-35H	360	G	NONE
35A-3510	420	F	G
35B-3500	30	G	F
35B-3514	60	F	F
35H-3550	100	G	NONE
35H-35J	160	F	NONE
35I-3552	140	F	NONE
35K-35KA	150	G	G
35K-35M	180	G	G

Table C1. (Cont'd).

Section ID	Length (ft)	Steam	Condensate
35KA-3549	400	G	G
35KA-3570	40	F	F
36A-3615	160	G	G
36A-3622	90	ABANDONED	
36B-35K	380	G	G
3726-3724	130	F	P
3726-3728	140	F	P
37A-3580	620	G	G
37A-3726	220	F	P
TOTAL RATED (LF)	16895		
*Good in replaced areas around 3100			

Table C2. Aboveground pipe section condition ratings for the 5000 area.

Section ID	Length (ft)	Steam	Condensate
5126-51J	80	G	NONE
51J-5165	610	G	NONE
51J-51K	130	G	NONE
51K-5179	260	G	NONE
51L-5101	480	G	NOT RATED
51L-51R	960	F	NOT RATED
51R-5188	260	G	NONE
52B-5307	560	F	NOT RATED
5695-5697	560	F	NOT RATED
56C-56D	780	F-P	G
56D-56E	400	G	NONE
56D-57A	440	G	G
56E-5648	360	F	NONE
56FA-56K	1445	F-P	SHUTOFF
56K-5695	290	F	NOT RATED
TOTAL RATED (LF)	7615		

Appendix D: Worksheet for Determining Potential Savings Associated With Returning Condensate

Figure D1 contains a worksheet for calculating the potential cost savings that could be realized from returning condensate instead of dumping it. The dumping of condensate requires the addition of makeup water at the boiler to replace what has been lost. The calculation takes into account the cost of the makeup water, the cost of energy to heat the water, and the cost of treatment chemicals.

PROCEDURE: (1) Enter data to right of heavy bar "%"
(2) Complete form referring to designated charts.

Hot Water Temperature (condensate return)	$\%T_H=$	°F
Cold Water Temperature (make up)	$\%T_C=$	°F
Difference in Temperature (T_H-T_C)	$\Delta T=$	°F
Chart 1 *Find T_H on the x-axis *read C_T on the y-axis	$C_T=$	Btu/°F*gal ≈8.34
Energy Content of 1 Gallon $I_1=\Delta T*C_T$	$I_1=$	Btu/gal
Velocity of Condensate Return	$\%V=$	ft/sec
$\mu = V(12in/ft)$	$\mu=$	in/sec
Inner Diameter of Condensate Pipe	$\%d=$	in
Radius of Condensate Pipe $(r=d/2)$	$r=$	in
Chart 2 *Find T_H on the x-axis *Read V_g on the y-axis	$V_g=$	in³/gal ≈231
Condensate Flow rate $I_2=\mu\pi r^2/V_g$	$I_2=$	gal/sec
Fraction of Year System is Operational (full year=1.0; 4 months=0.33)	$\%f_1=$	[0.0-1.0]
Fraction of Condensate Returned	$\%f_2=$	[0.0-1.0]
Energy Make-up Per Year $I_3=f_1*(1-f_2)*I_1*I_2*(31.54)$	$I_3=$	MBtu/yr
Price of Energy	$\%P_E=$	\$/MBtu
Cost to Heat Condensate Make-up Water Per Year $(C_1=I_3*P_E)$	$C_1=$	\$/yr
Total Cost of Water + Chemical Treatment per Gallon (make-up water)	$\%P_C=$	\$/gal
Yearly Cost of Water + Chemicals $C_2=I_2*P_C(3.154x10^7 sec/yr)$	$C_2=$	\$/yr
Total Cost (potential savings of condensate return line repair/replacement) $C_T=C_1+C_2$	$C_T=$	\$/yr

Figure D1. Worksheet for calculating cost savings related to recycling condensate instead of dumping it.

Chart 1: cp vs T (see line 4 of worksheet).

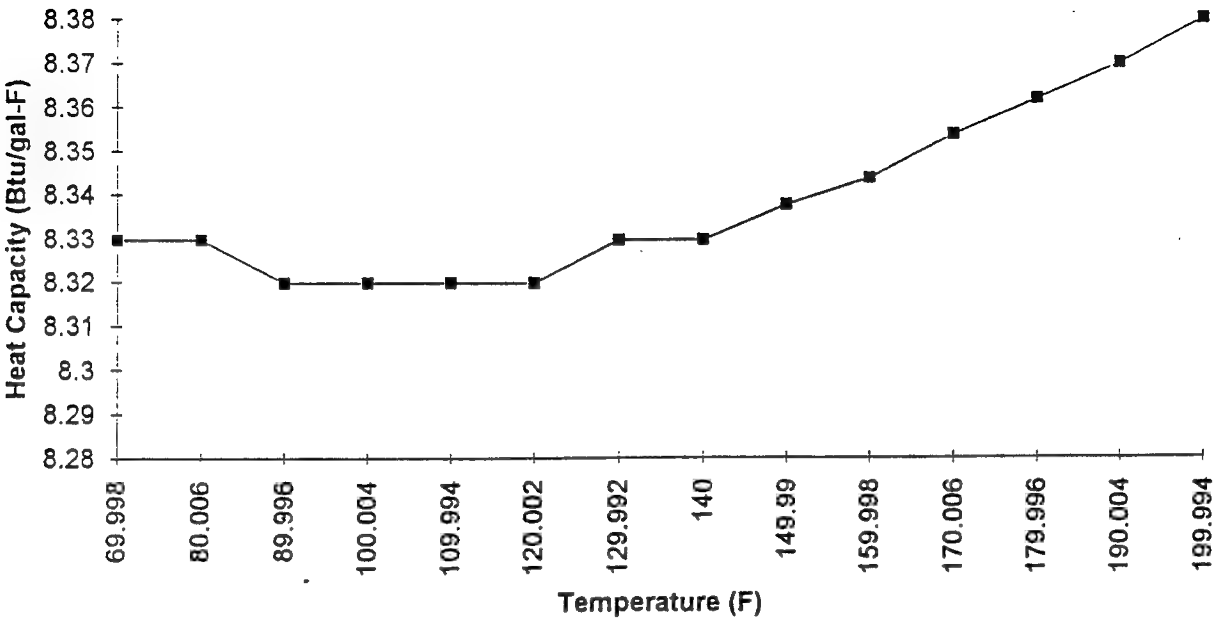


Chart 2: in^3/gal vs T (see line 10 of worksheet).

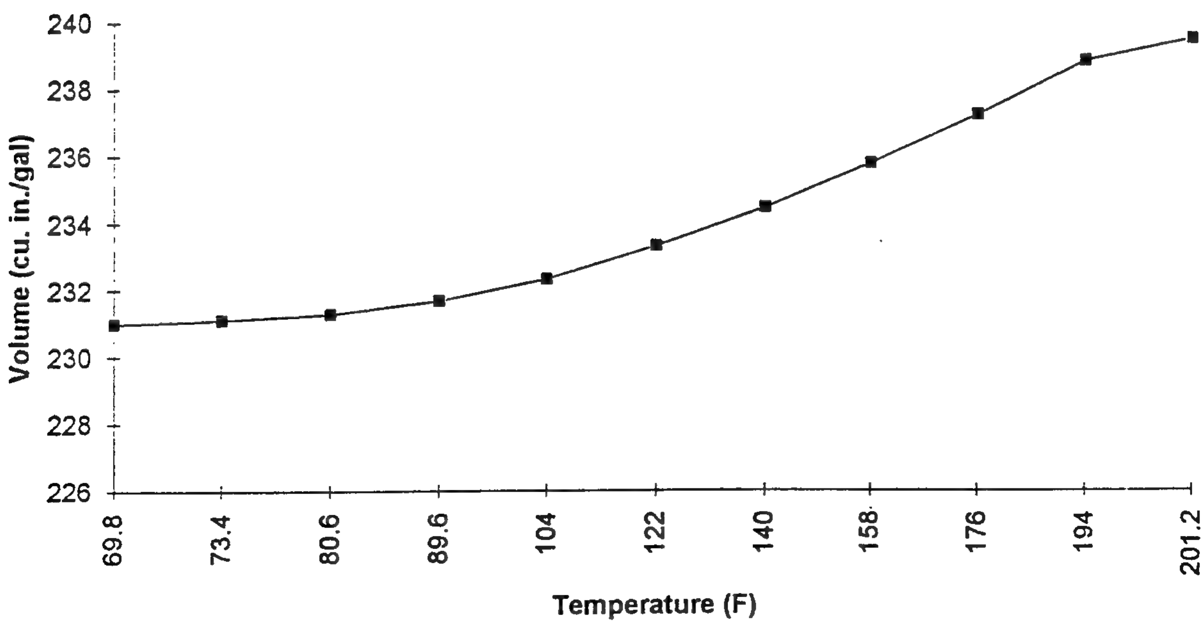


Figure D1. (Cont'd.)

Appendix E: Excerpt From CEGS 02695: Site Classification Procedure

The following text is a direct excerpt from CEGS 02695 detailing the site classification procedure for heat distribution systems.

****

DEPARTMENT OF THE ARMY CEGS-02695 (May 1991)
U.S. ARMY CORPS OF ENGINEERS ------------------------
Superseding
CEGS-02695 (March 1989)

GUIDE SPECIFICATION FOR MILITARY CONSTRUCTION

****

SECTION 02695

PREAPPROVED UNDERGROUND HEAT DISTRIBUTION SYSTEM

05/91

****

NOTE: This guide specification covers the requirements for an insulated underground heat distribution system and/or condensate return system of the preapproved and pre-engineered type. This guide specification is to be used in the preparation of project specifications in accordance with ER 1110-345-720.

****

PART 1 GENERAL

****

NOTE F: Classification of the site conditions for the underground heat distribution system will be based on the following criteria:

a. Underground Water Condition Classification

If at all practicable, a soils engineer familiar with the underground water conditions at the site

should be employed to establish the site classification. Site classifications are defined in Table A. If underground water conditions at the site are not available, a detailed site classification survey should be made. This survey should be conducted within the framework of the following guidelines:

(1) The survey should be made after the general layout of the system has been determined and should cover the entire length of the proposed system.

(2) If at all possible, the survey should be conducted during the time of the year when the water table is at its highest point. If this is not possible, water table measurements should be corrected to indicate conditions likely to exist at the time of year when the water table is at its highest point.

(3) As a minimum, information on groundwater conditions, soil types, terrain, and precipitation rates/irrigation practices in the area of the system should be collected.

(4) Information on terrain and precipitation rates/irrigation practices may be obtained from available records at the installation.

(5) Information on water table conditions and soil types will be obtained through borings, test pits, or other suitable exploratory means. Generally, a boring or test pit should be made at least every 100 feet along the line of the proposed system, and each exploratory hole should extend to a level at least 5 feet below the anticipated elevation of the bottom of the system. If a significant difference in underground conditions is found at adjacent exploratory points, additional explorations should be made between those points in order to determine more precisely where the change occurs.

Upon completion of the site classification survey, each exploration point should be classified as A, B, C, or D on the basis of the criteria presented in Table B. Soil types given in Table B are based on the soil classification system presented in ASTM D 2487. When doubt exists as to the proper classification of a point, the next higher classification should be assigned; e.g., if a

certain point could be considered either B or C, it should be assigned a B classification. Those decisions, like many engineering decisions, frequently will require the exercise of judgment on the part of the responsible engineer. The worst underground water condition encountered between any two valve manholes shall determine the class of system to be installed in that section of the system.

b. Soil Corrosiveness Classification

The soil at the site should be classified as corrosive or noncorrosive on the basis of the following criteria:

(1) Corrosive -- The soil resistivity is less than 30,000 ohms-centimeter (ohm-cm) or stray direct currents can be detected underground.

(2) Noncorrosive -- The soil resistivity is 30,000 ohm-cm or greater and no stray direct currents can be detected underground.

The classification should be made by an experienced corrosion engineer based on a field survey of the site carried out in accordance with recognized guidelines for conducting such surveys. When the survey indicates that the soil at the site is corrosive, the system shall be cathodically protected.

c. Soil pH

If there is any reason to suspect that the soil pH will be less than 5.0 anywhere along the proposed path of the system, pH measurements should be made at pipeline depth at close intervals along the proposed route, and all locations at which the pH is less than 5.0 should be indicated in the contract documents. Soil pH should be determined by an experienced soils engineer, preferably the same engineer responsible for other soil engineering work.

d. Soil Stability

The load-bearing qualities of the soil in which the system will be installed should be investigated by an experienced soils engineer, again preferably the same engineer responsible for other soils engineering work, and the location and nature of potential soil problems should be identified.

Table A. SITE CLASSIFICATION DEFINITIONS

Site Classification	General Conditions for Classification
A - Severe	1. The water table is expected to be frequently above the bottom of the system and surface water is expected to accumulate and remain for long periods in the soil surrounding the system. 2. The water table is expected to be occasionally above the bottom of the system and surface water is expected to accumulate and remain for long periods in the soil surrounding the system.
B - Bad	1. The water table is expected to be occasionally above the bottom of the system and surface water is expected to accumulate and remain for short periods (or not at all) in the soil surrounding the system. 2. The water table is expected never to be above the bottom of the system but surface water is expected to accumulate and remain for short periods in the soil surrounding the system.
C - Moderate	The water table is expected never to be above the bottom of the system but surface water is expected to accumulate and remain for short periods in the soil surrounding the system.
D - Mild	The water table is expected never to be above the bottom of the system and surface water is not expected to accumulate or remain in the soil surrounding the system.

Table B. SITE CLASSIFICATION CRITERIA

Site Classification (Note 1)	Water Table Level	Soil Types (Note 2)	Terrain	Precipitation Rates or Irrigation Practices in Area
A	Water table within 1 foot of bottom of system	Any	Any	Any
	Water table within 5 feet of bottom of system	GC, SC, CL, CH,	Any	Any
B	Water table within 5 feet of bottom of system	GW, GP, SW, SP	Any	Any
	No groundwater encountered	GC, SC, CL, CH, OH	Any	Equivalent to 3 in. or more in any one month or 20 in. or more in one year
C	No groundwater encountered	GM, SM, ML, OL,	Any	Equivalent to 3 in. or more in any one month or 20 in. or more in one year
	No groundwater encountered	GC, SC, CL, CH, OH	Any except low areas	Equivalent to less than 3 in. in any one month or less than 20 in. in one year.
D	No groundwater encountered	GW, GP, SW, SP	Any	Any
	No groundwater encountered	GM, SM, ML, OL, MH	Any	Equivalent to less than 3 in. in any one month or less than 20 in. in one year.

Note 1: See Table A. SITE CLASSIFICATION DEFINITIONS.

Note 2: See ASTM D 2487 for Soil Classifications.

Appendix F: Material Safety Data Sheets (MSDS) for Boiler Water Treatment Chemicals Used at Edgewood Area

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MATERIAL SAFETY DATA SHEET

VESTAL LABORATORIES

I - PRODUCT IDENTIFICATION

COMPANY NAME: Calgon Vestal Laboratories	
ADDRESS: 5035 Manchester Avenue St. Louis, MO 63110	Tel No: (314)535-1810 Nights: (314)862-2000 CHEMTREC: (800)424-9300
PRODUCT NAME: CB-260	Product No.: 1724

Synonyms: Reducing Agent

II - HAZARDOUS INGREDIENTS OF MIXTURES

MATERIAL: (CAS#)	% By Wt.	TLV	PEL
Sodium Sulfite (7757-83-7)	<15	N/A	N/A

III- PHYSICAL DATA

Vapor Pressure, mm Hg: Like Water Evaporation Rate(ether=1): N/AV Solubility in H2O: Complete Freezing Point F: N/AV Boiling Point F: >212 Specific Gravity H2O=1 @25C: 1.14 - 1.16	Vapor Density (Air=1)60-90F: Like H2O % Volatile by wt. @80% pH @ Solution 7.2-7.8 pH as Distributed: N/A Appearance: Dark amber liquid Odor: Slight chemical odor

IV - FIRE AND EXPLOSION

Flash Point F: Not flammable	Flammable Limits: N/A

Extinguishing Media: Product is not flammable.

Special Fire Fighting Procedures: None

Unusual Fire and Explosion Hazards: None

V - REACTIVITY DATA

Stability - Conditions to avoid: None known

Incompatibility: Strong oxidizers

Hazardous Decomposition Products: Oxides of sulfur when heated to decomposition.

Conditions Contributing to Hazardous Polymerization: None known

(Cont'd on Page 2)

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CB-260

VI - HEALTH HAZARD DATA

EFFECTS OF OVEREXPOSURE (Medical Conditions Aggravated/Target Organ Effects, A. ACUTE (Primary Route of Exposure) EYES and SKIN:On the basis of animal testing,we would not expect this product to produce any skin or eye irritation. INGESTION:Results from acute toxicity testing show that the material would not be considered toxic as defined by the CPSC protocols.

B.SUBCHRONIC,CHRONIC,OTHER: No available information was found.

VII - EMERGENCY AND FIRST AID PROCEDURES

Good First Aid should be followed in all cases of exposure.
EYES:In case of eye contact,flush with plenty of water for at least 15 minutes.If irritation develops,call a physician.

VIII - SPILL OR LEAK PROCEDURES

Spill Management: Dike area to contain as much spilled material as possible.Remove any remaining material by absorbing on vermiculite or other suitable material and place in sealed container for disposal.

Waste Disposal Methods: Flush with plenty of water.Dispose of in accordance with local,state and federal regulations.

IX - PROTECTION INFORMATION/CONTROL MEASURES

Respiratory: Not required	Eye: Not required	Glove: Not required

Other Clothing and Equipment: Not required

Ventilation: Normal

X - SPECIAL PRECAUTIONS

Precautions to be taken in Handling and Storing: Wash thoroughly after handling.Keep container closed.Exercise caution in the storage and handling of all chemical substances.

Additional Information: Read and observe all label precautions.

Prepared by:R.C.Jente

Revision Date:08/12/87

Seller makes no warranty, expressed or implied, concerning the use of this product other than indicated on the label. Buyer assumes all risk of use and/or handling of this material when such use and/or handling is contrary to label instructions.

While Seller believes that the information contained herein is accurate, such information is offered solely for its customers' consideration and verification under their specific use conditions. This information is not to be deemed a warranty or representation of any kind for which Seller assumes legal responsibility.

01-20-1993 13:52 14106712617 DIRECTORATE PUBLIC WORK/EA HEAT/ P.04

MATERIAL SAFETY DATA SHEET

VESTAL LABORATORIES

I - PRODUCT IDENTIFICATION

COMPANY NAME: Calgon Vestal Laboratories

ADDRESS: 5035 Manchester Avenue St. Louis, MO 63110	Tel No: (314)535-1810 Nights: (314)862-2000 CHEMTREC: (800)424-9300
PRODUCT NAME: CB-409	Product No.: 1198

Synonyms: Caustic pH Adjuster

II - HAZARDOUS INGREDIENTS OF MIXTURES

MATERIAL: (CAS#)	(ORAL LD50)	% By Wt.	TLV	PEL
Sodium Hydroxide (1310-73-2)	(140mg/kg)	50	2mg/m3	2mg/m3

III- PHYSICAL DATA

Vapor Pressure, mm Hg: Like Water	Vapor Density (Air=1)60-90F: Like H2O
Evaporation Rate(ether=1): N/A	% Volatile by wt <5
Solubility in H2O: Complete	pH @ Solution N/A
Freezing Point F: N/A	pH as Distributed: (undiluted) >13
Boiling Point F: 288	Appearance: Water-white to turbid liq.
Specific Gravity H2O=1 @25C: 1.53	Odor: Characteristic

IV - FIRE AND EXPLOSION

Flash Point F: N/A	Flammable Limits: N/A

Extinguishing Media: Product is not flammable or combustible.Use media appropriate for the primary source of fire.

Special Fire Fighting Procedures: Use caution when fighting any fire involving chemicals.A self-contained breathing apparatus is essential.

Unusual Fire and Explosion Hazards: Contact with some metals can generate hydrogen gas.

V - REACTIVITY DATA

Stability - Conditions to avoid: None known

Incompatibility: Acids.Contact with some metals such as magnesium, aluminum,zinc(galvanized),tin,chromium,brass and bronze may generate hydrogen.

Hazardous Decomposition Products: Unknown

Conditions Contributing to Hazardous Polymerization: Product will not polymerize.

(Cont'd on Page 2)

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CB-409

VI - HEALTH HAZARD DATA

EFFECTS OF OVEREXPOSURE (Medical Conditions Aggravated/Target Organ Effects,
A. ACUTE (Primary Route of Exposure) EYES:Contact with eyes will result in severe burns,permanent tissue damage and possible blindness.SKIN: (Primary Route of Exposure)Contact with skin will result in severe irritation or burns with possible scarring.INGESTION:Will result in severe burns of the mouth,throat,esophagus and stomach with severe damage of contacted tissue.Can result in internal bleeding and death. INHALATION:Inhalation of mists can result in severe respiratory irritation and possible pneumonitis.
B.SUBCHRONIC,CHRONIC,OTHER: No available information was found.

VII - EMERGENCY AND FIRST AID PROCEDURES

EYES:Immediately flush eyes with plenty of water for at least 15 minutes.See a physician.SKIN:Immediately wash with soap and plenty of water for at least 15 minutes while removing contaminated clothing. Seek medical aid.INGESTION:If swallowed,DO NOT induce vomiting.Give milk if available or water to dilute.Call physician or Poison Control Center.Never give anything by mouth to an unconscious person. INHALATION:If inhaled,remove to fresh air.If not breathing,give artificial respiration.If breathing is difficult,give oxygen.Seek medical aid.

VIII - SPILL OR LEAK PROCEDURES

Spill Management: Contain spill.Absorb on absorbent material and place in a D.O.T.-approved container for disposal.Flush spill residue to the sanitary sewer with large dilutions of water where local restrictions permit.

Waste Disposal Methods: Dispose of in accordance with all federal, state and local regulations.

IX - PROTECTION INFORMATION/CONTROL MEASURES

Respiratory: Where engineering controls are impractical,use NIOSH-approved respirator appropriate for conditions.	Eye: Chemical goggles and face shield	Glove: Rubber

Other Clothing and Equipment: Rubber apron and rubber boots

Ventilation: Local exhaust ventilation recommended to control air concentrations below established limits.

X - SPECIAL PRECAUTIONS

Precautions to be taken in Handling and Storing: Do not get in eyes,on skin or clothing.Keep container closed.Wash thoroughly after handling.
Additional Information: Always add slowly to water.Read and observe all labeled precautions.

Prepared by:R.C.Jente Revision Date:08/03/87

Seller makes no warranty, expressed or implied, concerning the use of this product other than indicated on the label. Buyer assumes all risk of use and/or handling of this material when such use and/or handling is contrary to label instructions.

While Seller believes that the information contained herein is accurate, such information is offered solely for its customers' consideration and verification under their specific use conditions. This information is not to be deemed a warranty or representation of any kind for which Seller assumes legal responsi-

01-20-1993 13:54 14106712617 DIRECTORATE PUBLIC WORK/EA HEAT/ P.06

MATERIAL SAFETY DATA SHEET

I - PRODUCT IDENTIFICATION

COMPANY NAME: Calgon Vestal Laboratories

ADDRESS: 5035 Manchester Avenue St. Louis, MO 63110	Tel No: (314)535-1810 Nights: (314)862-2000 CHEMTREC: (800)424-9390
PRODUCT NAME: CB-150	Product No.: 1722

Synonyms: Phosphate

II - HAZARDOUS INGREDIENTS OF MIXTURES

MATERIAL: (CAS#)	% By Wt.	TLV	PEL
According to the OSHA Hazard Communications Standard, 29CFR 1910.1200, this product contains no hazardous ingredients.	N/A	N/A	N/A

III- PHYSICAL DATA

Vapor Pressure, mm Hg: Like Water	Vapor Density (Air=1)80-90F: Like H2O
Evaporation Rate(ether=1): N/AV	% Volatile by wt 80
Solubility in H2O: Complete	pH @ Solution N/A
Freezing Point F: N/AV	pH as Distributed: 6.0
Boiling Point F: >212	Appearance: White liquid
Specific Gravity H2O=1 @25C: 1.17	Odor: N/AV

IV - FIRE AND EXPLOSION

Flash Point F: Not flammable	Flammable Limits: N/A

Extinguishing Media: Product is not flammable.

Special Fire Fighting Procedures: None

Unusual Fire and Explosion Hazards: None

V - REACTIVITY DATA

Stability - Conditions to avoid: N/AV

Incompatibility: Strong oxidizers

Hazardous Decomposition Products: Unknown

Conditions Contributing to Hazardous Polymerization: N/A

(Cont'd on Page 2)

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CB-150

VI - HEALTH HAZARD DATA

EFFECTS OF OVEREXPOSURE (Medical Conditions Aggravated/Target Organ Effects,
A. ACUTE (Primary Route of Exposure) EYES and SKIN:Not expected to produce any skin or eye irritation.INGESTION:Product is not considered to be toxic.
B.SUBCHRONIC,CHRONIC,OTHER: No available information was found.

VII - EMERGENCY AND FIRST AID PROCEDURES

EYES:In case of eye contact,flush with cool water for at least 15 minutes.If irritation develops,call a physician.SKIN:If irritation develops,flush area and contact a physician.Good first aid should be followed in all cases of exposure.

VIII - SPILL OR LEAK PROCEDURES

Spill Management: Dispose of in accordance with local,state and federal regulations.Dike area to contain as much spilled material as possible Remove any remaining material by absorbing on vermiculite or other suitable material and place in a sealed container for disposal.

Waste Disposal Methods: Flush with plenty of water.Dispose of in accordance with local,state and federal regulations.

IX - PROTECTION INFORMATION/CONTROL MEASURES

Respiratory: Not required	Eye: Not required	Glove: Gloves recommended

Other Clothing and Equipment: Not required

Ventilation: Normal

X - SPECIAL PRECAUTIONS

Precautions to be taken in Handling and Storing: Wash thoroughly after handling.Keep container closed.Exercise caution in the storage and handling of all chemical substances.

Additional Information: Read and observe label precautions.

Prepared by:R.C.Jente Revision Date:08/06/87

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01-20-1993 13:55 14106712617 DIRECTORATE PUBLIC WORK/EA HEAT/ P.08

CALGON VESTAL LABORATORIES

MATERIAL SAFETY DATA SHEET

I - PRODUCT IDENTIFICATION

COMPANY NAME: Calgon Vestal Laboratories	
ADDRESS: 5035 Manchester Avenue St. Louis, MO 63110	Tel No: (314)535-1810 Nights: (314)535-1395 CHEMTREC: (800)424-9300
PRODUCT NAME: MagnAMINE-327	Product No.: 1740

Synonyms: Condensate corrosion inhibitor

II - HAZARDOUS INGREDIENTS OF MIXTURES

MATERIAL:	(CAS #)	% By Wt.	TLV	PEL
morpholine	(110-91-8)	< 30	20ppm (skin)	20ppm
diethylaminoethanol	(100-37-8)	< 25	10ppm (skin)	10ppm

III- PHYSICAL DATA

Vapor Pressure, mm Hg: unknown	Vapor Density (Air=1)80-90F: unknown
Evaporation Rate(ether=1): unknown	% Volatile by wt 100
Solubility in H2O: complete	pH @ Solution NA
Freezing Point F: NA	pH as Distributed: 11.6-12.0
Boiling Point F: NA	Appearance: clear yellow liquid
Specific Gravity H2O=1 @25C: 1.00-1.04	Odor: "fishy" amine odor

IV - FIRE AND EXPLOSION

Flash Point F: 188 (TOC)	Flammable Limits: Unknown

Extinguishing Media: CO2, dry chemical, alcohol foam, water spray.

Special Fire Fighting Procedures: Firefighters should wear protective clothing and use NIOSH-approved breathing apparatus.

Unusual Fire and Explosion Hazards: Emits toxic vapors under fire conditions. Vapors are heavier than air and may travel along ground to distant source of ignition.

V - REACTIVITY DATA

Stability - Conditions to avoid: Keep away from heat and open flame.

Incompatibility: Oxidizing agents, reactive metals, strong acids.

Hazardous Decomposition Products: Carbon monoxide, carbon dioxide, ammonia, disodium oxide, oxides of nitrogen.

Conditions Contributing to Hazardous Polymerization: Will not occur.

(Cont'd on Page 2)

MagnAMINE-327

VI - HEALTH HAZARD DATA

EFFECTS OF OVEREXPOSURE (Medical Conditions Aggravated/Target Organ Effects,
A. ACUTE (Primary Route of Exposure) INHALATION:May cause respiratory irritation, shortness of breath, dizziness if inhaled. (Primary Route of Exposure) EYES:Fumes irritating to mucous membranes. Will cause severe burns on contact. (Primary Route of Exposure) SKIN:Causes severe irritation or burns. Penetration may be slow and extent of damage depends on duration of exposure. INGESTION:Causes burns to mouth, throat and stomach.
B. SUBCHRONIC,CHRONIC,OTHER: None known.

VII - EMERGENCY AND FIRST AID PROCEDURES

EYES:Flush with water for 15 minutes and get medical attention. SKIN: Remove contaminated clothing and shoes. Wash exposed areas with soap and plenty of water. If irritation develops, get medical attention. INHALATION:Remove to fresh air. If symptoms persist, get medical attention. INGESTION:Give water or milk to dilute. Do NOT induce vomiting. Get immediate medical attention.

VIII - SPILL OR LEAK PROCEDURES

Spill Management: Contain spill. Extinguish ignition sources. Ventilate area. Absorb onto inert material. Flush residue with water.

Waste Disposal Methods: Incinerate in accordance with all local, state and federal regulations.

IX - PROTECTION INFORMATION/CONTROL MEASURES

Respiratory: NIOSH-recommended for organic vapors if air limits are exceeded.	Eye: Safety goggles	Glove: Vinyl or neoprene

Other Clothing and Equipment: Protective clothing.

Ventilation: Local exhaust ventilation recommended.

X - SPECIAL PRECAUTIONS

Precautions to be taken in Handling and Storing: Keep away from heat, sparks and flame. Use ony with adequate ventilation. Avoid breathing vapors.

Additional Information: Avoid contact with eyes, skin and clothing. Wash thoroughly after handling.

Prepared by: D. Godward Revision Date:08/08/91

Seller makes no warranty, expressed or implied, concerning the use of this product other than indicated on the label. Buyer assumes all risk of use and/or handling of this material when such use and/or handling is contrary to label instructions.

While Seller believes that the information contained herein is accurate, such information is offered solely for its customers' consideration and verification under their specific use conditions. This information is not to be deemed a warranty or representation of any kind for which Seller assumes legal responsibility.

Appendix G: Information on Lead-Based Paint Testing

Lead-based primers, especially red lead primers, were commonly used on industrial structures until recently. There are no laws that prohibit their use on industrial facilities, but removing the paints during maintenance poses health and disposal problems. Structures as old as the Edgewood aboveground heat distribution system are likely to be primed with lead-based paint.

Before any maintenance or demolition of structures, the coatings should be tested for lead. There are three methods for testing lead in paint. The most reliable is laboratory analysis of paint chips. Another method is x-ray fluorescence (XRF) analysis. This method has the advantage of providing a direct on-the-spot readout of lead content, but it is not as accurate as laboratory analysis. There is potential for false negative and false positive readings when lead levels are low. It is, however, a good screening tool when high lead concentrations are expected. The third method is chemical spot test kits. This a qualitative test only; it gives no estimation of the amount of lead present.

When planning maintenance or demolition involving lead-painted structures, several regulations must be considered. The Occupational Safety and Health Administration (OSHA) has enacted an Interim Final Lead in Construction Standard (1926.62), which applies to all construction workers who may be exposed to lead on the job. Workers exposed to 30 micrograms of lead per cubic meter or more must be given medical surveillance and training in lead hazards. The maximum allowable exposure for workers is 50 micrograms of lead per cubic meter averaged over an 8-hour working day.

Demolition or maintenance of lead-painted structures may generate a hazardous waste. The *Resource Conservation and Recovery Act* (RCRA) prescribes how waste is to be contained, stored, transported, and disposed of. The test for determining whether a waste is to be classified as hazardous is the Toxicity Characteristic Leaching Procedure (TCLP) test. Wastes that leach more lead than 5 ppm are to be classified as hazardous.

Additional information is available from the USACERL Paint Technology Center, 217-352-6511, ext. 427.

Appendix H: The Army Boiler Water Quality Assurance Program

The following information paper was provided by the U.S. Army Center for Public Works (CECPW-ES). CECPW-ES is in charge of the Army's Boiler Water Quality Assurance program.

INFORMATION PAPER

CECPW-ES
14 Feb 94

SUBJECT: Boiler Water Quality Assurance Analysis Services

1. PURPOSE: To provide information on the availability of Boiler Water Quality Assurance services for improvement of boiler plant operations.

2. FACTS:

a. The control of water chemistry in boiler water and condensate return systems is very important for maintaining proper boiler operation. Boiler plants with poor control over their water chemistry will experience higher energy and operating costs, more plant shutdowns, higher maintenance, higher equipment replacement costs and decreased safety. It is important to have Quality Assurance (QA) performed by an independent consultant to sustain good water chemistry control. A good QA evaluation will verify the effectiveness of the DEH program and provide recommendations for making improvements in the control of a particular boiler plant's water chemistry program.

b. The QA check analyses are now available through a contract with Puckorius & Associates, Inc (P&A). Their address is attached.

c. Individual installations can fund these services themselves by preparing a delivery order directly to the contractor. The QA services must be requested through an executed delivery order before sending samples to the contractor. The procedure is fairly simple.

- Prepare a delivery order to request QA services for six months of boiler system water samples.
- Describe the contract services required and cite the contract number in the delivery order. A sample description is attached.
- After Puckorius has received the executed delivery order, send samples and in-plant test results to them.

d. Puckorius & Associates will perform the analysis, prepare a report with recommendations and send it to the installation within two weeks of receiving a sample. Sample shipping containers and new sample bottles will also be sent to the installation. If you need additional sample bottles and containers, please contact Puckorius & Associates. Questions or comments regarding these services should be directed to the names below.

Nelson Labbe /DSN 656-5202
Andrew Jackson /DSN 656-5204

Address of Puckorius & Associates, Inc. for sample analysis

Puckorius & Associates, Inc. P.O. Box 2440 1202 Hwy. 74, Suite 210 Evergreen, CO 80439	phone: fax:	(303) 674-9897 (303) 674-1453

Sample description of services

Item	Description of Supply or Services	Quantity	Unit	Unit Price	Total Cost
1.	CLIN 2AA, Boiler Water Analysis	24	ea	$113.00	$2712.00
2.	CLIN 2AB, Condensate Analysis	4	ea	126.00	504.00
3.	CLIN 2AC, Condensed Steam Analysis	1	ea	45.00	45.00
4.	CLIN 2AD, Hot Water Boiler Analysis	8	ea	63.00	504.00
5.	CLIN 2AE, Feedwater Analysis	4	ea	110.00	440.00
6.	CLIN 2AF, Deposit Analysis	1	ea	150.00	150.00
7.	CLIN 2AG, Corrosion Tester	2	ea	200.00	400.00
				TOTAL:	4,755.00

Send Analysis Reports to : *Show the address that you want the analysis reports sent to.*

Contract: DACA31-92-D-0063
Contractor: Puckorius & Associates, Inc.
P.O. Box 2440
1202 Hwy. 74, Suite 210
Evergreen, CO 80439
(303) 674-9897

Notes:

Adjust the quantities to whatever number you need. Try to order enough for six months worth of samples at a time. Once an order is prepared with a description similar to the one above, the rest of the ordering procedure is the same as any other purchase request placed for your boiler plants.

A copy of the delivery order must be sent to U.S. Army Center for Public Works , ATTN: CECPW-ES (Andrew Jackson), 7701 Telegraph Road, Alexandria, VA 22310-3862, *so that U.S. Army Center for Public Works (USACPW) can monitor contract work for your installation. The above prices are good until Oct 94. Prices and contract CLIN numbers change each option year in October. Copies of the contract are available upon request.*

If you have any boiler water treatment problems or questions regarding the contractor's work, contact USACPW.

Appendix I: Cathodic Protection Testing and Criteria and CP Diagnostic Program

How Cathodic Protection Works

When cathodic protection (CP) is applied to a structure, the structure's electrical potential changes. Understanding these changes in potential will help the user understand whether CP systems are functioning through the application of CP criteria.

The electrical potential of a structure is always measured relative to a stable "reference electrode" or "half cell." Thus, the potential that is reported is actually the potential difference between the structure of interest and the reference electrode. For underground structures, the most commonly used reference electrode is the copper-copper sulfate ($Cu/CuSO_4$) electrode. Other types of reference electrodes are sometimes used in other environments; for example silver- silver chloride is commonly used in seawater applications. To assure that potential readings are properly interpreted, the reference electrode used should always be noted. For example, readings taken with a copper-copper sulfate reference cell should be reported as ##.### volts vs $Cu/CuSO_4$.

When cathodic protection is properly applied, it produces a change in the potential of a structure with respect to a reference electrode placed in the soil in proximity to that structure. The cathodic protection current makes the measured potential more negative than the potential was before the current was applied. The amount of change produced is a measure of the effectiveness of the cathodic protection at that location.

The changes in electrical potential of the structure (with respect to a $Cu/CuSO_4$ reference electrode) that occur when the cathodic protection current is applied are depicted graphically in Figure I1. Before current is applied, the structure is at its original, or "native" potential. When the current is applied, there is a change in potential in the negative direction at the instant the current is turned on. As the current is continuously applied over an extended period of time, the potential tends to increase negatively because of polarization. Polarization of a structure occurs over a long period and a structure may not be entirely polarized even after the cathodic protection system has been in continuous operation for many months. If the current is interrupted after the structure has polarized, the potential becomes less negative

at the instant of turn-off. The potential then begins to decay, or depolarize, back to the original or native potential. Well coated structures tend to polarize and depolarize more quickly than uncoated or poorly coated structures.

Cathodic Protection Criteria

Structure-to-electrolyte potential measurements are analyzed to determine whether a structure is cathodically protected. (For a discussion of structure-to-electrolyte potential measurements, see "Structure-to-Electrolyte Potential Measurements" later in this appendix. Determination of whether or not protection is being achieved is made through the use of cathodic protection criteria. Unfortunately, there is not one simple criterion that has been accepted by all cathodic protection engineers and that can be practicably measured in the field under all circumstances.

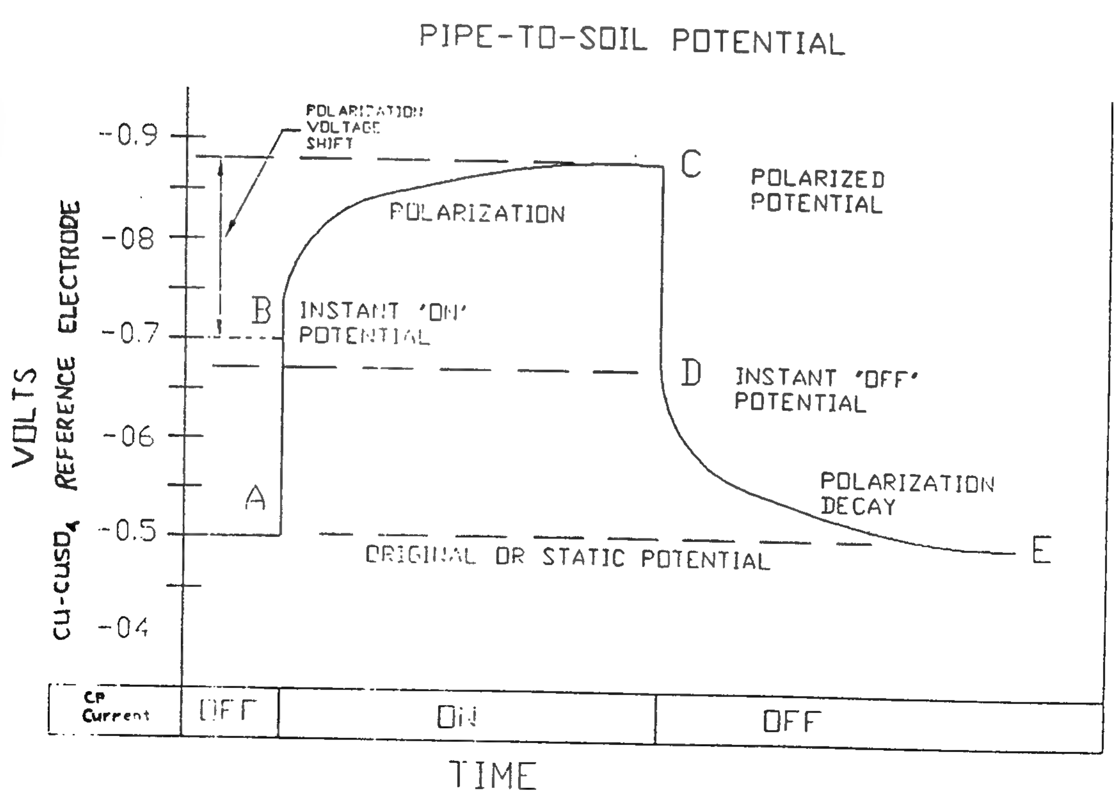

Figure I1. Electric potential shifts that occur when protective current is applied to a steel structure.

Guidance on the criteria of cathodic protection for external corrosion control on underground structures is found in two recommended practices (RPs) published by the National Association of Corrosion Engineers (NACE). These are RP0169-92, *Control of External Corrosion on Underground or Submerged Metallic Piping Systems*, and RP-02-85, *Control of External Corrosion on Metallic Buried, Partially Buried, or Submerged Liquid Storage Systems*. The criteria for cathodic protection of steel given in these two RPs were previously identical, but RP0169-92 was recently revised (April 1992) and the criteria contained therein were updated. RP-02-85 is currently undergoing revision, and it is believed that the criteria contained therein will be updated the same as RP0169-92. The revisions are mostly concerned with the handling of the IR drop present in structure-to-soil potential readings and the elimination of criteria that are impractical for field use. Thus, because the most recent guidance on criteria for protection of underground steel is given in RP0169-92, this is the guidance that will be quoted and explained here.

1. A negative (cathodic) potential of at least 850 mV with the cathodic protection applied. This potential is measured with respect to a saturated $Cu/CuSO_4$ reference electrode contacting the electrolyte. Voltage drops other than those across the structure-to-electrolyte boundary must be considered for valid interpretation of this voltage measurement.
2. A negative polarized potential of at least 850 mV relative to a saturated $Cu/CuSO_4$ reference electrode. (Polarized potential is defined as the potential across the structure/electrolyte interface that is the sum of the corrosion potential and the cathodic polarization.)
3. A minimum of 100 mV of cathodic polarization between the structure surface and a stable reference electrode contacting the electrolyte. The formation or decay of polarization can be measured to satisfy this criterion.

Understanding the IR Drop

The -0.85 V on-potential criterion states that voltage drops other than those across the structure-to-electrolyte boundary must be considered when interpreting the measurements. The other two criteria refer to polarization and polarized potential. This is of utmost concern when evaluating potential measurements because only polarization provides cathodic protection. No protection is provided by the voltage drops other than those across the structure-to-electrolyte (i.e., structure-to-soil) boundary.

Unfortunately, when structure-to-soil potentials are measured in the field, the measurement includes not only the voltage drop across the structure-to-soil boundary, but also includes other voltage drops in the circuit. Corrosion engineers refer to these

other, extraneous voltage drops as IR drop or IR error. This IR drop must be minimized when taking measurements so the voltage drop measured is as close as possible to the actual voltage drop across the structure-to-soil boundary. Figure I2 shows the region of the potential-vs-time curve which is considered to be the IR drop.

Two IR drops are referred to: the *soil IR drop* and the *metal IR drop*. Husock (1979, pp 37-47) defines and explains these IR drops and offers suggestions for considering them in the interpretation of structure-to-soil potentials. (Note: "E" in the following description refers to the absolute value of the measured structure-to-soil potential.)

> It is the IR drops in the soil $(IR)_S$ and metal of the pipeline $(IR)_M$ that must be considered as shown in Figure I2 and the following equation:
>
> $$E = E_P + (IR)_M + (IR)_S$$
>
> where:
>
> E_P = the pipe-to-soil potential which exists between a hypothetical reference electrode immediately adjacent to the pipe surface and a metallic contact to the pipe close to the reference electrode.
>
> $(IR)_S$ = Voltage (IR) drop in soil between the hypothetical reference electrode placed immediately adjacent to the pipe surface and the actual position of the reference electrode placed at grade (or other location).
>
> $(IR)_M$ = Voltage (IR) drop in pipe (often referred to as metal IR drop) between a point of metallic contact close to the reference electrode and the actual point of contact to the structure. . . .
>
> Both of these IR drops are an inherent part of the potential which is measured. On coated pipe, soil IR drop is not usually significant, but it can be considerable on bare pipes especially in higher resistivity soils. Metal IR drops, particularly where there is substantial line current, must be considered on all lines, both coated and bare, particularly where there is some distance between the contact point and the reference electrode location.

In the application of the NACE potential criterion (i.e., -0.85 V. for steel), regardless of structure material, the potential must be interpreted as a polarized value. Structure-to-electrolyte measurements for comparison to the chosen criterion must be free of IR drop error. Sometimes this can be achieved by placing the reference electrode immediately adjacent to the structure or, alternatively, by measuring the potential instantaneously after the cathodic protection current is interrupted (sometimes called *instant-off* potentials).

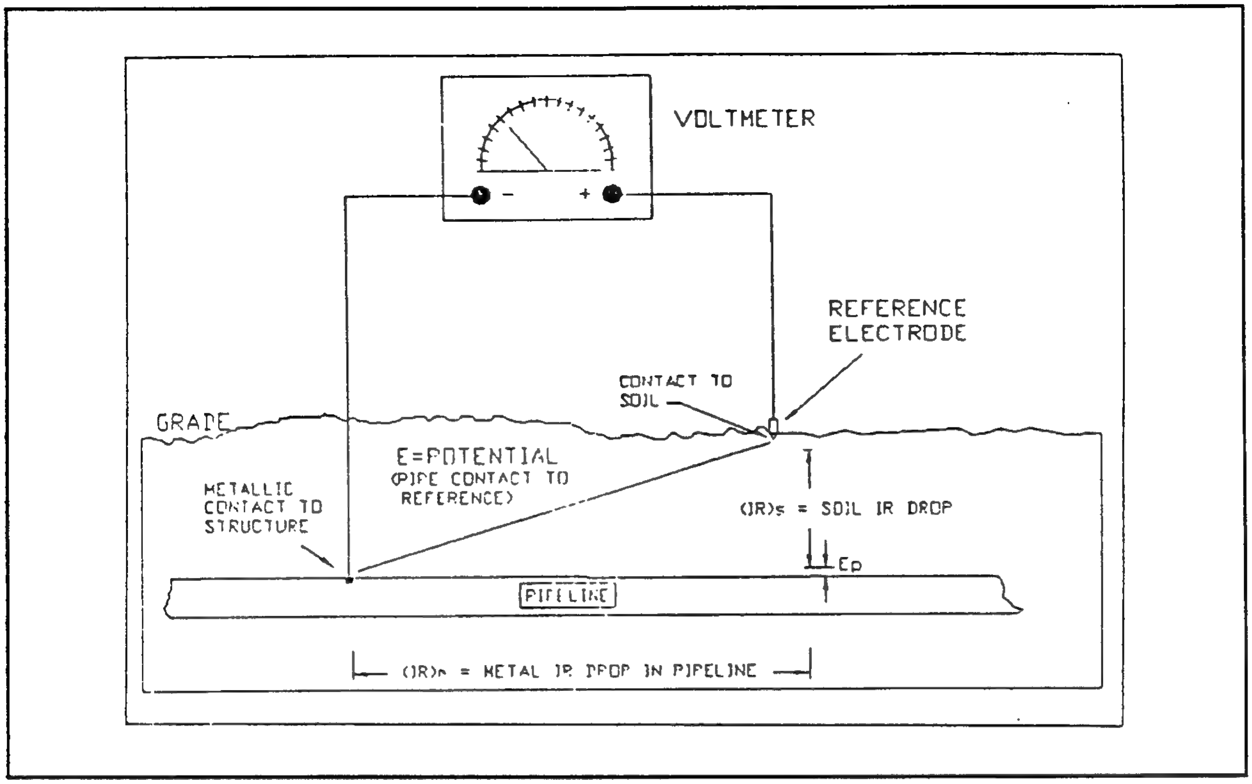

Figure I2. IR drops in structure-to-soil potential.

The IR drop also affects the 100 mV polarization voltage shift criterion. According to the 100 mV criterion, if the corrosion potential is polarized electronegatively by at least 100 mV, protection is considered to be achieved. To apply this criterion it is necessary to record structure corrosion potentials before the energization of the cathodic protection system, and then to measure polarized potentials at the same locations after the cathodic protection system has been placed in operation. Since polarization is a function of time, it is sometimes advantageous—especially on bare structures—to allow the cathodic protection system to operate for a period of time before conducting the potential survey. It is imperative that all potentials measured after energization be free of IR drop so a valid comparison to the native potentials can be made. If baseline corrosion potential data were not recorded before energization, the cathodic protection system can be turned off to allow the structure to depolarize so that the baseline data can be obtained. The disadvantage of this is that the structure could remain unprotected for an extended period of time.

Selection of a Criterion

As stated in NACE RP-01-69, no one criterion for evaluating the effectiveness of cathodic protection has proven satisfactory for all conditions. The selection of the

criterion to be used should be made carefully, preferably with the assistance of a corrosion engineer who has expertise in cathodic protection. To select the proper criterion for a particular situation, it is important to understand each criterion and its limitations. If the results obtained with the particular criterion selected indicate that the level of cathodic protection on the structure does not meet that criterion, one does not have the freedom to simply select another criterion which may be more easily met. The criterion *must* be appropriate for the application.

Each criterion described above has advantages and disadvantages that affect its applicability to a given situation. Table I1 presents the appropriate uses for each criterion. For further details, the reader should consult ESL TR-79-14.

Structure-To-Electrolyte Potential Measurements

Overview

As explained above, the structure-to-electrolyte potential is one of the most important measurements made for cathodic protection because it is used to determine whether a structure is receiving the intended corrosion protection. These are the measurements that are compared with the criteria described above. USACPW typically recommends that the measurements be taken annually.

The electrical potential of a structure is always measured relative to a stable *reference electrode* or *half cell*. Thus, the potential that is reported is actually the potential

Table I3. Summary of cathodic protection criteria.

CRITERIA: CHARACTERISTICS	-0.85 Volt	100 Millivolt Polarization Shift	-0.85 Volt Instant Off
Frequency of Use	Most Often Used	Seldom Used	Rarely Used
Readings Taken with CP Current:	ON	OFF and ON then OFF	OFF
Ease of Field Use	Easiest	Not Easy	Suitable
Suitable for Use in Stray Current Areas	Yes	No	No
Must Consider IR Drop	Yes	No	No
Primarily Used On	Well Coated Structures	Bare Structures	Well Coated Structures
Can Also Be Used When Interconnected With	Copper	Aluminum or Galvanized Steel	Copper

difference between the structure of interest and the reference electrode. If the potential of the structure is lower than that of the reference cell, it is reported as negative (-). If the potential of the structure is higher than that of the reference cell, it is reported as positive (+). An analogy for this is the use of "sea level" as a reference point for elevation measurements. For underground structures, the most commonly used reference electrode is the copper-copper sulfate ($Cu/CuSO_4$) electrode. Measurements are reported as "##.### volts referenced to $Cu/CuSO_4$."

Measurement Procedure: Sacrificial Systems

Structure-to-electrolyte potential measurements in sacrificial systems are conducted using the arrangement shown in Figure I3. One terminal of a high-resistance voltmeter is connected to the structure or component to be tested and the other terminal is connected to the $Cu/CuSO_4$ reference cell. The electrode is placed on the soil as close as possible to the structure. The potential is then read off of the voltmeter. Possible points of connection to the buried structure are at:

- cathodic protection test stations (best)
- risers
- hydrants
- exposed service entrances or manways

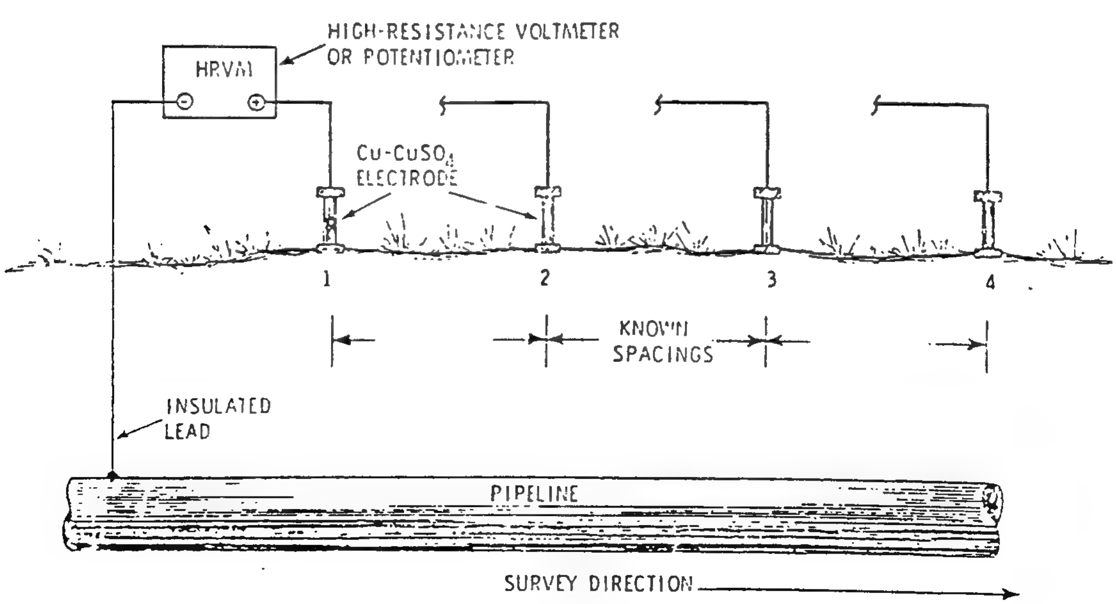

Figure I3. Structure-to-electrolyte potential measurement setup.

- meter installations
- valve installations.

Determine the polarity (+ or -) of the reading by examining the voltmeter connections. By convention, most corrosion engineers connect the negative terminal to the structure and the positive terminal to the reference cell. This requires the polarity of the measurement to be reversed when it is recorded since the electrode is the point of reference. For example, if the reading on the meter is 0.88 V, the reading would be recorded as -0.88 referenced to $Cu/CuSO_4$. Always examine the meter connections to be sure of the polarity.

The reference cell should be placed as close as possible to the structure to minimize the soil IR drop (IR_s). Usually, soil resistivities and magnitude of current flow in sacrificial systems are not large enough to cause a significant IR drop.
To ensure meaningful results:

1. Take readings with the reference cell directly over the structure to be tested.
2. Make sure there is good electrical contact between the plug of the reference electrode and the soil; it may be necessary to scrape down to moist earth or to dampen the soil with water.
3. If a test station is not available, it is important to make sure there is good electrical contact with the structure; test prods or clamps should be scraped on the metal surface or a metal file to penetrate any dirt or oxide coatings.
4. Verify that the correct polarity (+ or -) of the measurement has been reported by examining the voltmeter connections.

Knowledge of the electrical continuity within the structure being tested is *extremely important* when taking potential readings. In situations where the structures are electrically continuous, electric contact may be made at an easily accessible point and the reference cell may simply be moved from one component to the other. If components of the system are electrically isolated, electrical contact with each system component must be made separately. If in doubt about the electrical continuity of components, *play it safe* by connecting to each component separately.

Measurement Procedure: Impressed Current Systems

As discussed previously, the IR drop is a significant source of error in obtaining potential measurements. This is particularly true in an impressed current system because of the larger magnitudes of current (and usually higher soil resistivities) involved. It is important to correct for the IR drop because in an active cathodic protection environment IR drop always causes potentials to indicate more protection

than actually exists. In other words, a reading that includes IR drop may show that a structure is cathodically protected when in reality it is not.

Two basic methods can be used for the measurement of IR-free potentials: (1) current interruption or instant-off readings and (2) use of a device that samples the potential waveform and determines the IR-free potential.

The most widely accepted method for correcting the IR drop is by conducting instant-off potential measurements. This is done by interrupting the cathodic protection current (i.e., turning off the rectifier or disconnecting sacrificial anodes) and reading the potential at the moment the current is interrupted. A high-resistance voltmeter may be used for this measurement, and the same connections are made as for sacrificial systems. If multiple current sources affect the structure being tested, current interruption must be synchronized (i.e., all sources must be interrupted at the same time). To do this automatically in an impressed current system, current interruptors can be installed at each rectifier and synchronized. Synchonized current interruption can also be achieved manually by posting one technician at each rectifier and communicating via two-way radio (walkie-talkie) to synchronize the shutting off of the rectifiers.

Several devices may be used to sample the potential waveform and determine the IR-free potential. Recently developed devices such as the waveform analyzer and the cathodic protection datalogger make this procedure relatively simple. These computerized devices actually analyze the potential waveform and automatically determine the point at which the current (and, consequently, the IR drop) is zero. An oscilloscope may also be used to analyze the waveform.

Facilities Under Pavement

It has been found that measuring structure-to-electrolyte potentials of structures under pavement by using a reference electrode in contact with the pavement will result in appreciable error. The most efficient way of getting accurate measurements is to install a permanent pavement insert with a removable plug that will allow insertion of a reference electrode. The hole beneath the insert should be filled with sand to within 4 in. of the top of the insert to allow the reference electrode to make contact with the sand.

If pavement inserts cannot be used or installed, structure-to-electrolyte measurements can be taken by positioning the reference electrode at a joint or crack in the pavement where contact can be made with the soil. This method may not be as accurate as the pavement insert method.

Interpretation of Measurements

Structure-to-soil potential measurements should be interpreted according to the cathodic protection criteria set forth in an earlier section of this chapter. If cathodic protection criteria are not met on any part of the structure, corrective action must be taken.

Testing for Electrical Isolation

Overview

If dielectric or isolating flanges or unions have been installed in a system, it is important to test them periodically to verify that isolation is still being maintained. The reason for this is that the cathodic protection system has been designed to protect a certain amount of pipe/tank surface area. If the dielectric joints fail and the protected structure becomes electrically continuous with another structure, the cathodic protection system suddenly must supply current for both structures. The anodes will be consumed more rapidly than the designer intended, and the life of the cathodic protection system will be shortened—sometimes dramatically if the additional structure has a much larger surface area than the originally protected structure.

Measurement Procedure and Interpretation

For buried structures, direct measurement of the insulation resistance of a joint is difficult because the conductivity of the soil effectively bypasses the joint. Some joints are located in valve pits or other locations where they are not in direct contact with the soil and are accessible for testing using the aboveground methods given in the next paragraph. Buried insulating flanges that are in direct contact with the soil should always be equipped with test stations for testing of the joint. At a two-wire test station, a test current of several amperes is applied. If the measured potential on the supposedly isolated section does not change, or if it changes to a more positive value, the insulation is effective. As explained above, an audio frequency pipe locator can also be used to test for isolation.

For aboveground isolation joints, more direct methods can be used to test the joint. Electric insulation testers are commercially available and are the preferred method for testing isolation joints. The two contact points protruding from the instrument are placed on either side of the joint, and the meter display will indicate whether current is passing from one side to the other. Or, structure-to-soil potentials can be measured

on each side of the joint. If there is an appreciable difference, the insulation is effective.

Faulty isolation joints should be replaced to ensure that the anodes are not consumed sooner than the design engineer intended.

Anode-to-Electrolyte Potentials

This measurement simply provides an indication of which lead wire is attached to the anode and is used mostly in sacrificial CP systems. The location of a buried anode may be pinpointed by moving the reference electrode and noting the location of highest (most negative) potential. An abnormally low potential may indicate a severed lead wire or a depleted anode. This measurement is conducted in the same way as the structure-to-electrolyte potential measurement described above, except that a connection is made to the anode instead of to the structure. This measurement should be performed when structure-to-soil potentials measurements are made.

Anode-to-Structure Current

The rate of anode metal loss directly depends on the rate of current flow between the structure and the anode. This current flow is measured to indicate whether the anode is operating properly and to allow approximation of the anode life.

Measurement Procedure

Anode-to-structure current is usually measured at the test station in a sacrificial system, or at the anode junction box in an impressed current system. The anode-to-structure current is measured by inserting an ammeter into the circuit between the anode and protected structure. This may involve physically disconnecting the lead wire to insert the meter (Figure I4). Beginning at the highest range of the instrument will avoid overloading and damaging the meter. Some test stations are equipped with a shunt of known resistance so current can be measured without breaking the circuit. If a shunt is available, measure the voltage drop across the shunt and use the conversion factor printed on the shunt to calculate the current (Figure I5).

Interpretation of Measurements

An anode-to-structure current of zero may indicate that a lead wire has been broken or that the anode has been consumed. The anode should be replaced. A marked

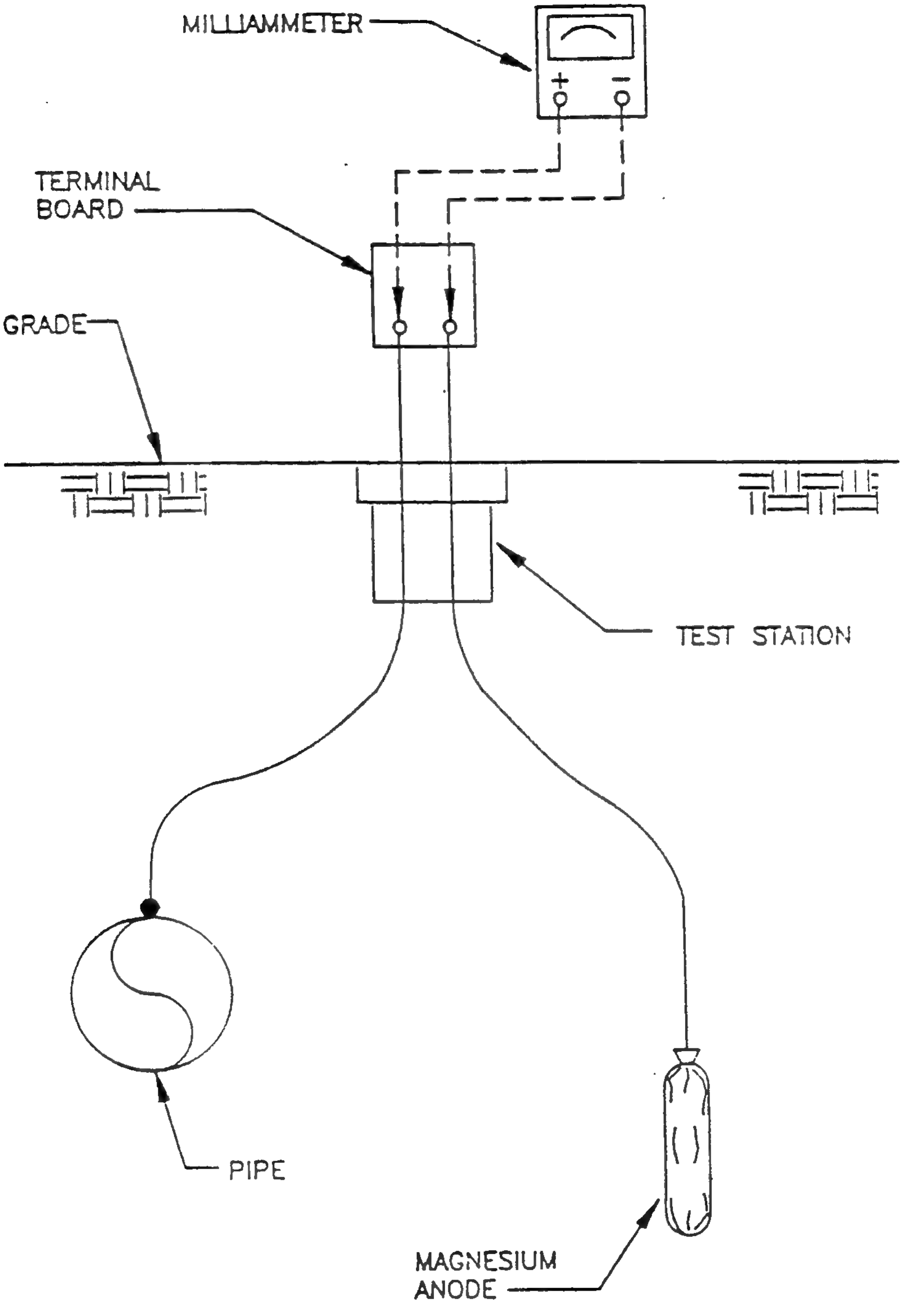

Figure I4. Measurement of anode-to-structure current using ammeter in series.

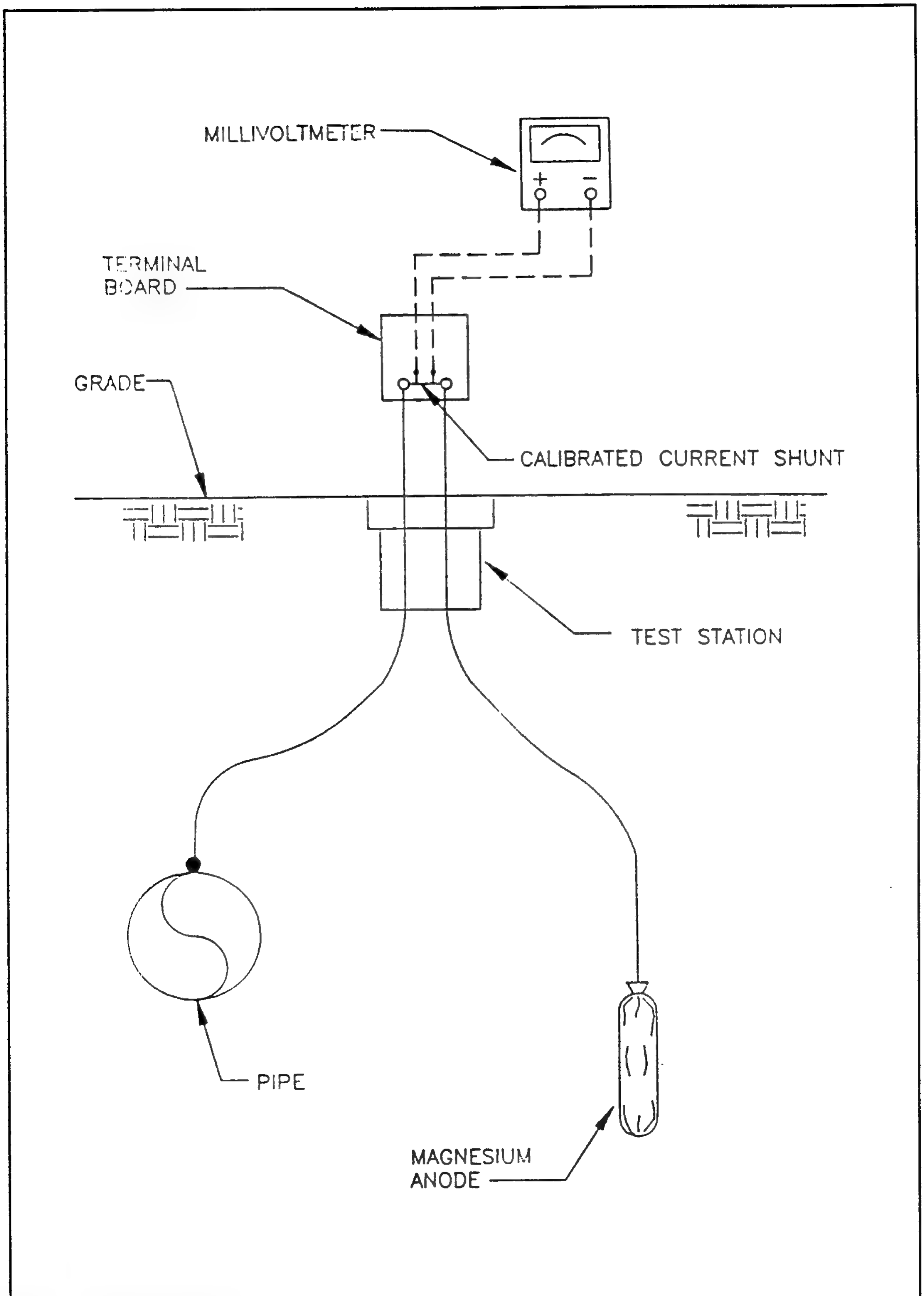

Figure I5. Measurement of anode-to-structure current using shunt and voltmeter.

decrease in the anode-to-structure current between tests may indicate that the anode is nearing the end of its life and will require replacement soon.

The USACERL CP Diagnostic Program

USACERL offers a software program that helps installation personnel more effectively manage and evaluate CP system data. Information about the CP Diagnostic program is presented in Figure I6. CP Diagnostic is available to installation DPWs at no charge.

US Army Corps
of Engineers
Construction Engineering
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Fact Sheet

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February 1994 (FM 36)

CATHODIC PROTECTION (CP) DIAGNOSTIC

The Problem

The Army owns and maintains approximately 20,000 underground fuel storage tanks (USTs); 4,000 miles of buried gas pipes; and 300 elevated water storage tanks. Millions of dollars are spent annually to repair corrosion damage to these structures. Many installations use cathodic protection (CP) systems to protect these structures against corrosion. If CP systems fail or malfunction, the structure is no longer protected. Proper maintenance of CP systems involves troubleshooting and the evaluation of large amounts of data. This is a difficult task for many installations because they do not have personnel trained in CP and corrosion control. In addition, U.S. Environmental Protection Agency (EPA) regulations have made it mandatory to monitor the CP systems protecting USTs and their piping so that corrosion protection is ensured. Assistance is needed in the evaluation, troubleshooting, and storage of CP system data.

The Technology

The U.S. Army Construction Engineering Research Laboratories (USACERL) has developed the CP Diagnostic computer program which operates on an IBM-AT or compatible microcomputer with hard drive and 640 kilobyte of random access memory. This program assists installations in evaluating, troubleshooting, and maintaining data on CP systems for underground piping, USTs, elevated water storage tanks, and civil works structures, such as miter and sector gates. Background information (e.g., structure data, anode and test point data, and rectifier specifications) and data from field measurements (e.g., structure-to-soil potential, anode currents, rectifier currents, and voltages) are loaded into the program. Based on the data, CP Diagnostic pinpoints malfunctioning systems which are not providing proper corrosion protection, as well as deteriorating systems whose performance has shown a marked decline over time. The CP Diagnostic program also generates data collection forms for the system inspector. USACERL has developed an expert system module which leads the user through a complete diagnostic procedure to determine causes and remedies for CP system failures and malfunctions. The system is written in the PROLOG computer language which is often used for expert systems.

An interface has been developed with a portable pen-based computer system to make the data collection process more efficient. Inspection forms are brought up on the screen, and

Figure I6. CP Diagnostic fact sheet.

the inspector uses the stylus attached to the computer to "write" information in the appropriate places on the screen. At the end of the day, information can be uploaded into the CP Diagnostic data base in the office. A module is currently under development which helps schedule CP system testing and repairs such that regulatory compliance is maintained.

Benefits/Savings

CP Diagnostic improves the reliability of CP systems and the structures that they protect. Malfunctioning CP systems are diagnosed so that they can be promptly repaired. Properly maintained CP systems reduce the chance of costly and potentially dangerous corrosion-induced failures of structures, including USTs, underground piping systems, elevated water storage tanks, and civil works structures, such as miter and sector gates. In addition, CP Diagnostic keeps easily accessible records which can be used to ensure compliance with the EPA corrosion protection regulations for USTs.

Status

The CP Diagnostic software and user manuals are currently available. The user manual is ADP Report M-91/24, *Cathodic Protection Diagnostic Computer Program for Sacrificial and Impressed Current Systems: Overview and Users Manual.* CP Diagnostic has been implemented at Fort Hood, TX, on the underground gas distribution system and on USTs. The program has also been implemented at Fort Carson, CO, on USTs. Implementation is under way at Fort Lee, VA; Fort Meade, MD; Fort Richardson, AK; Fort Wainwright, AK; and Aberdeen Proving Ground, MD. The Navy and the Air Force are also evaluating CP Diagnostic for use at their installations. A test version of the expert system module has been completed.

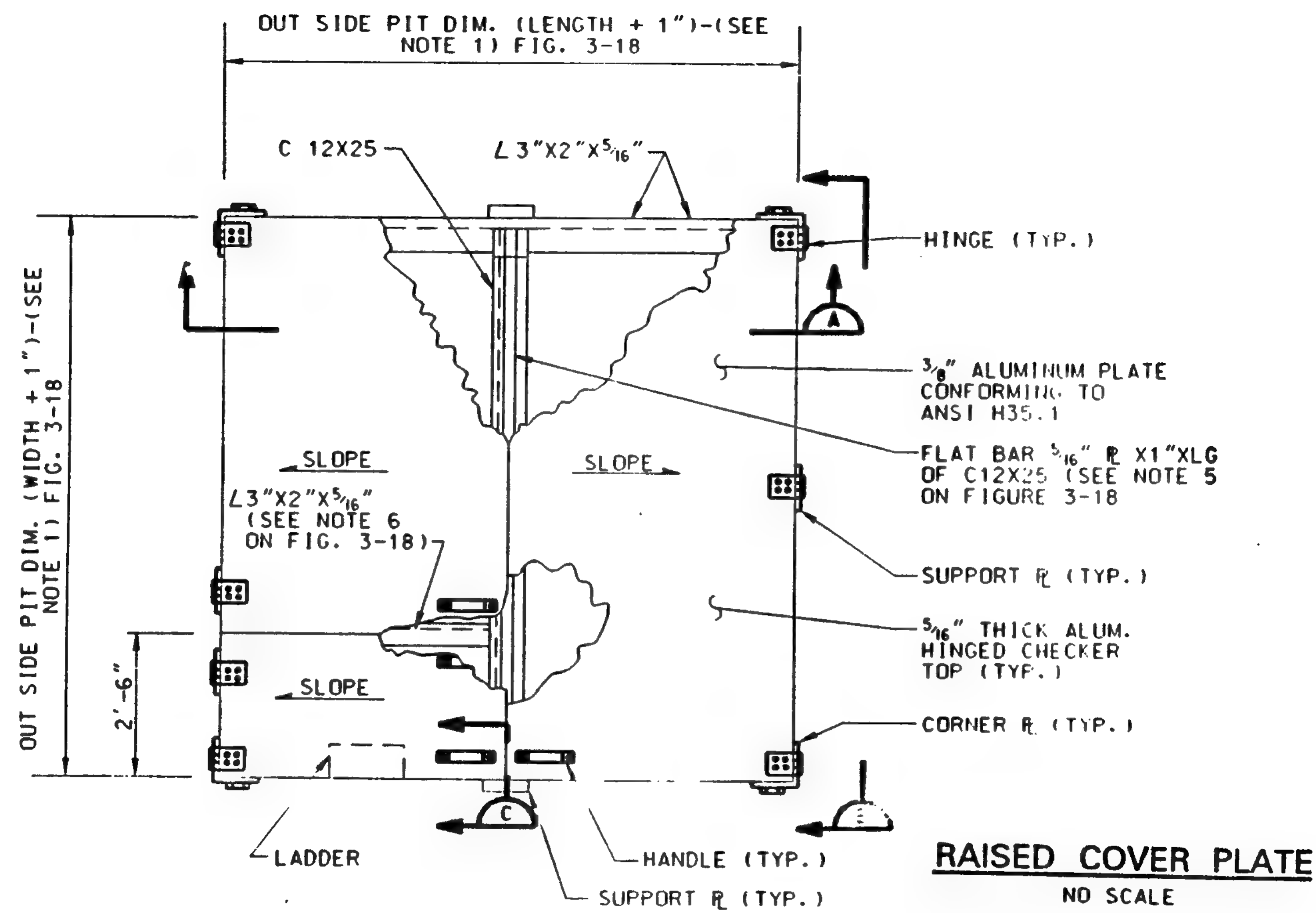
Points of Contact

USACERL POCs are Ms. Vicki Van Blaricum, COMM 217-373-6771, and Dr. Ashok Kumar, COMM 217-373-7235. Both can be reached toll-free 800-USA-CERL; FAX 217-373-6732; or USACERL, ATTN: CECER-FMC, P.O. Box 9005, Champaign, IL 61826-9005.

Figure I6. (Cont'd).

Appendix J: The Omaha Design for Manholes

The following figures are excerpted from Army TM 5-810-17 *Heating and Cooling Distribution Systems*. They provide information on the new "Omaha design" which should be used for new manhole construction.



Note to designer: Plate cover shown is designed for loadings up to 40 psf when spacing between sidewall and center supports is less than 3'6". Loadings or spacings greater than these must be designed for on a case-by-case basis.

Figure J1. Raised cover plate design.

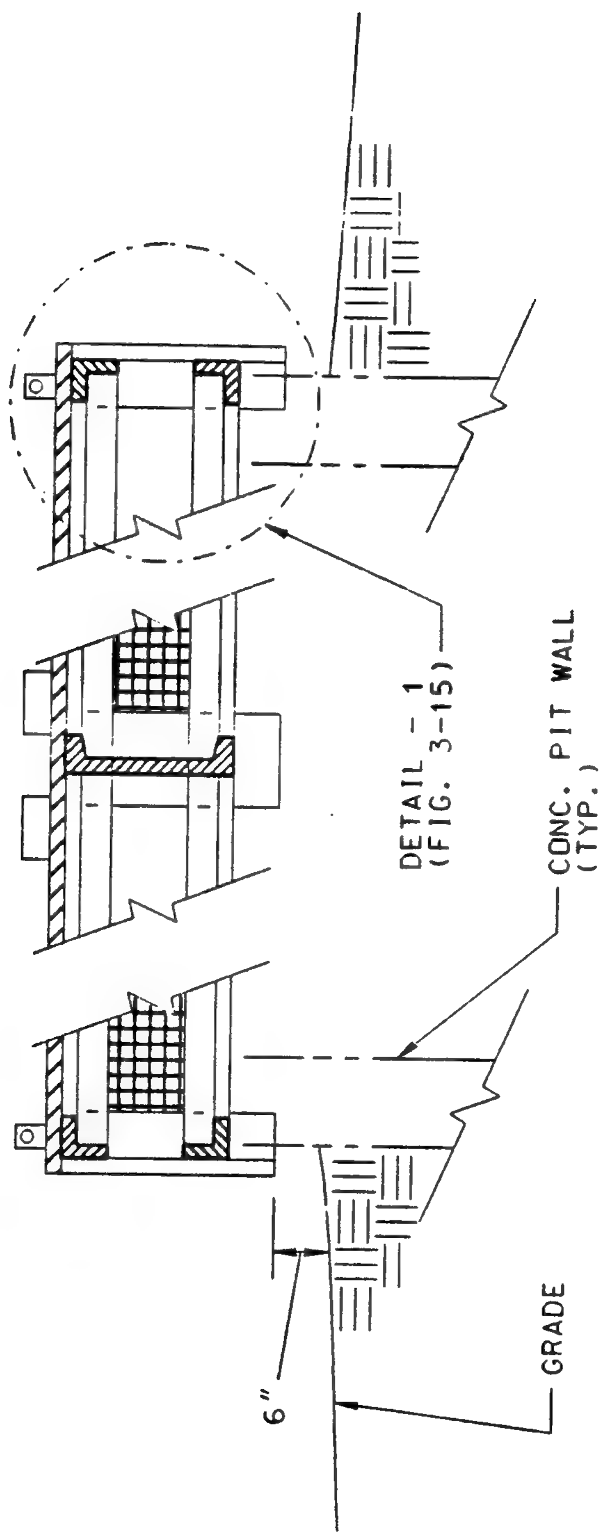


Figure J2. Section A-A of raised cover plate.

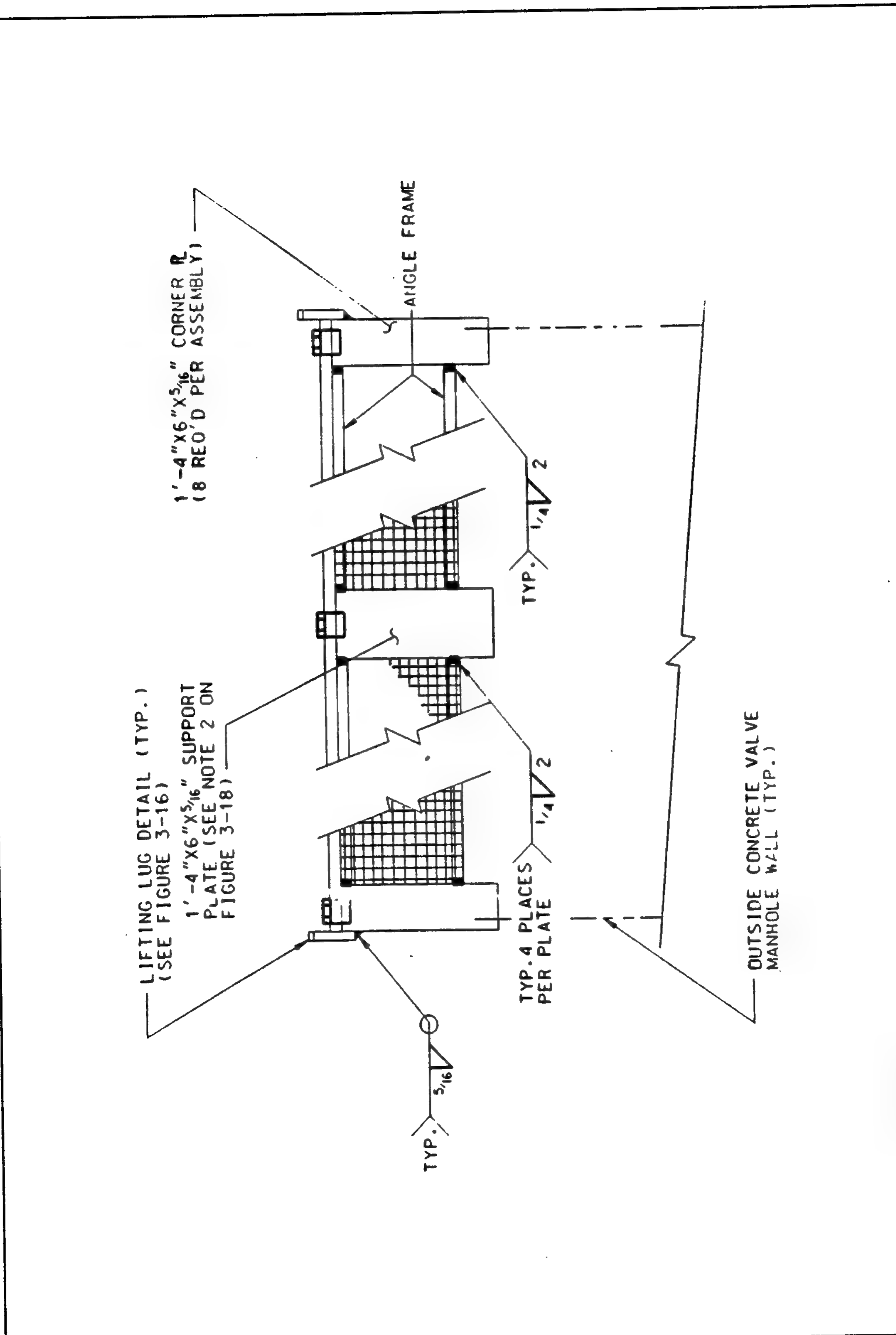


Figure J3. Section B-B of raised cover plate.

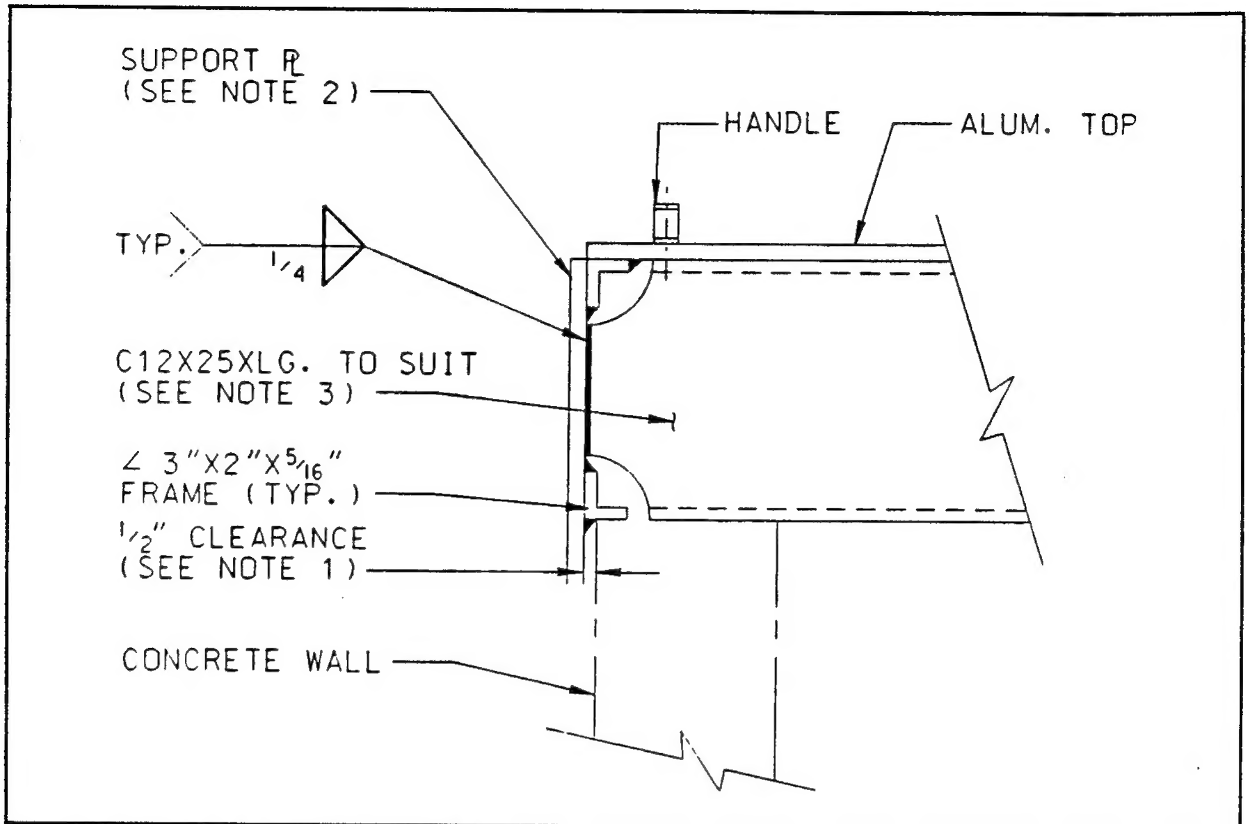


Figure J4. Section C-C of raised cover plate.

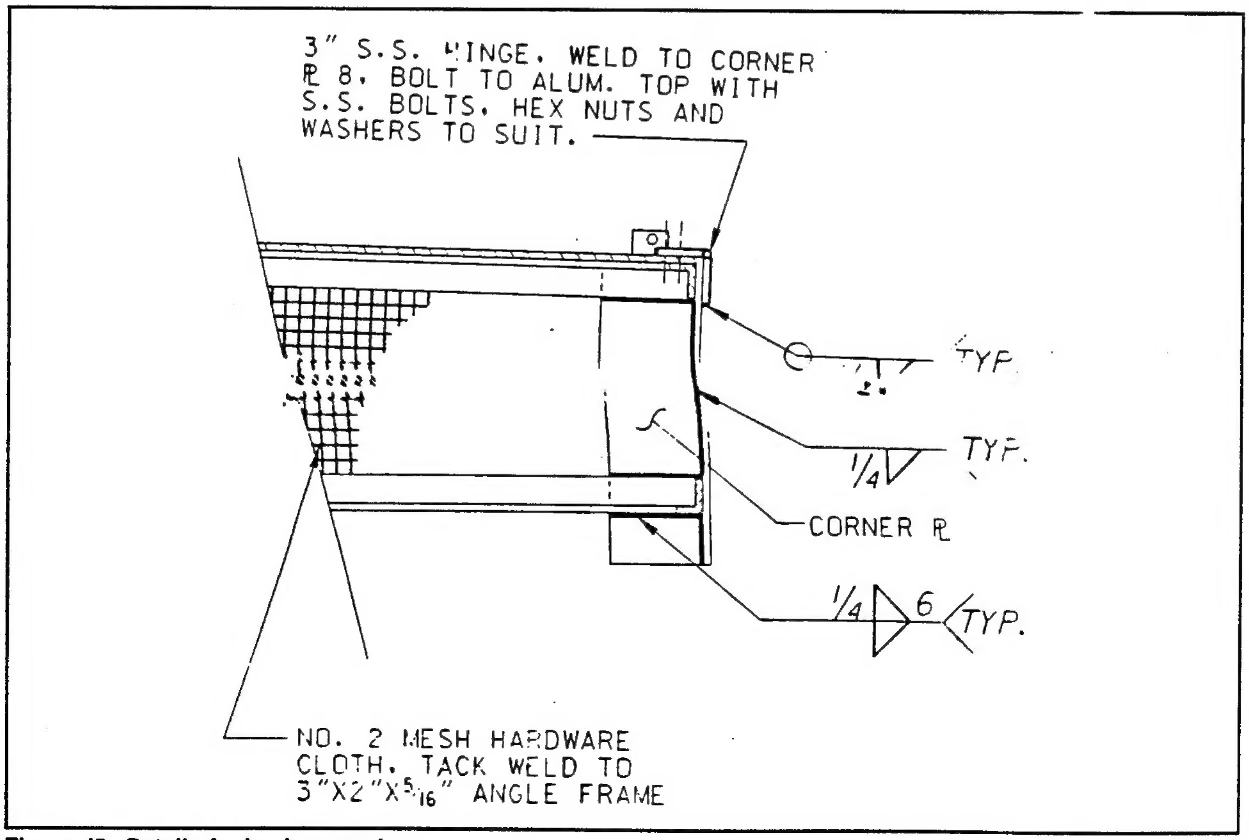


Figure J5. Detail of raised cover plate.

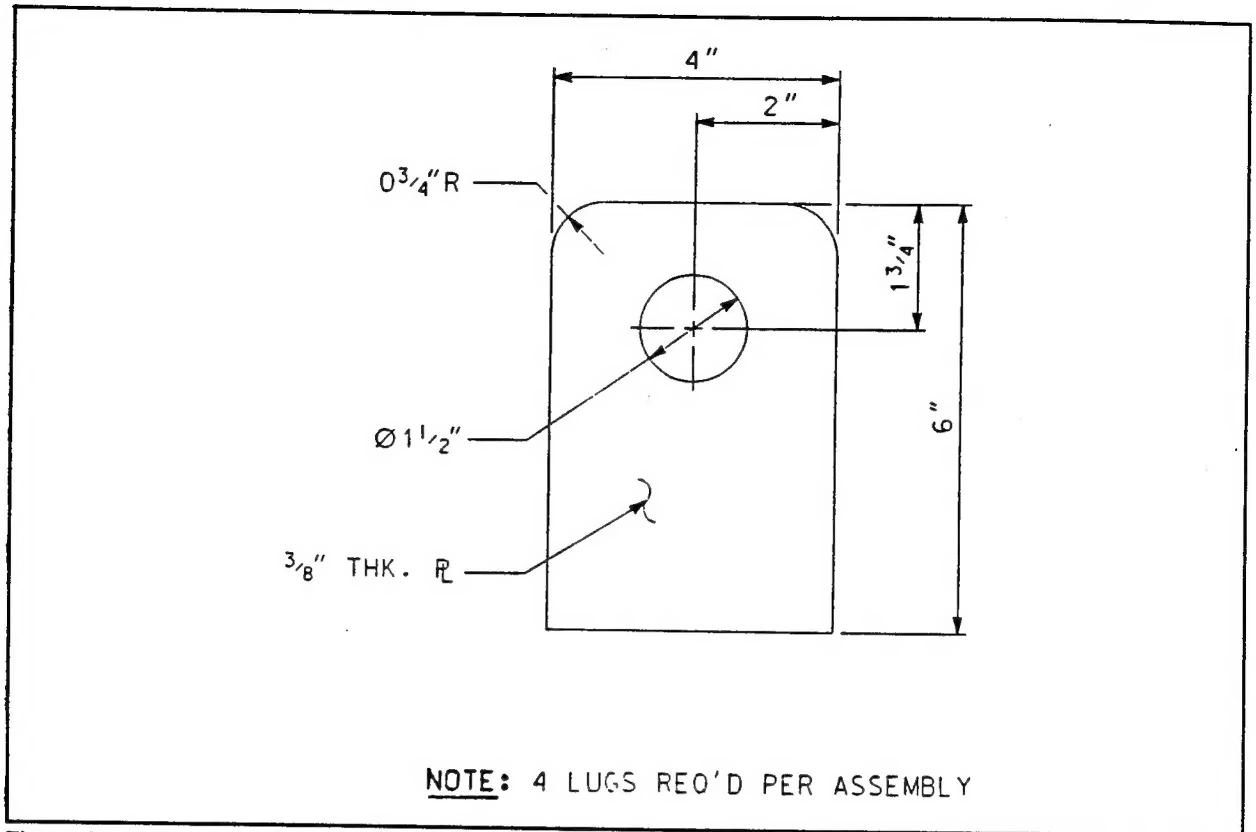


Figure J6. Lifting lug detail.

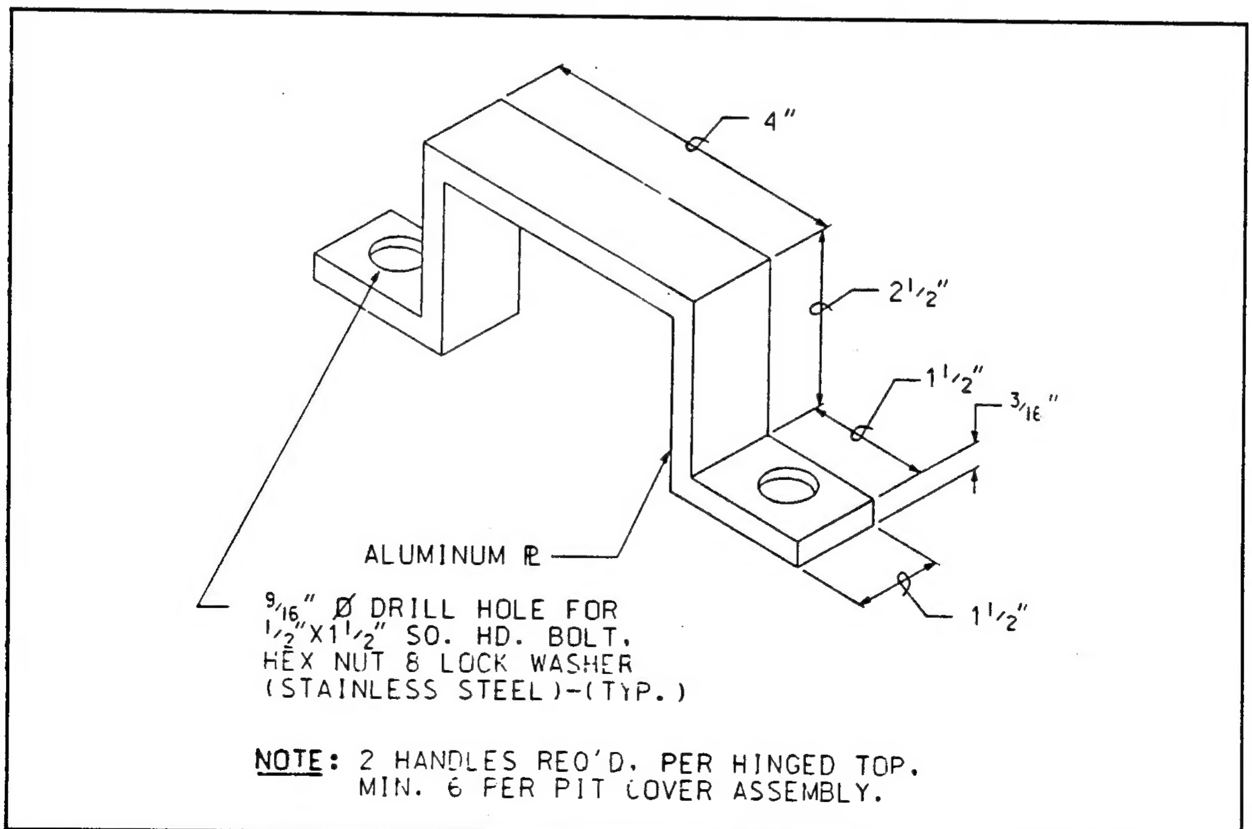


Figure J7. Handle detail.

1. FIELD VERIFY OUTSIDE DIMENSIONS OF NEW MANHOLE BEFORE CONSTRUCTING MANHOLE COVER ASSEMBLY. ADD 1" TO OUTSIDE MANHOLE DIMENSIONS (TO ALLOW FOR CLEARANCE) TO DETERMINE INSIDE ASSEMBLY DIMENSIONS.

2. EACH SUPPORT PLATE SHALL BE LOCATED HALFWAY BETWEEN CORNER PLATES AT 3 SIDES OF MANHOLE. 2 SUPPORT PLATES SHALL BE LOCATED BETWEEN 2 SPLIT ALUM. CHECKER TOP AT ONE SIDE OF MANHOLE.

3. SUPPORT CHANNELS SHALL BE C12X25XLG. TO EQUAL WIDTH OR LENGTH DIM. PLUS 1" TO SUIT INSIDE ASSEMBLY DIM. THE CHANNEL SHALL REST ON THE CONCRETE MANHOLE TOP AND THE ALUM. TOP SHALL REST ON THE FLAT BAR PLATE.

4. CHANNEL SUPPORT, CORNER PLATES, SUPPORT PLATES, ANGLE FRAME HARDWARE CLOTH, AND LIFTING LUGS SHALL BE HOT-DIPPED GALVANIZED BEFORE INSTALLATION ON VALVE MANHOLES.

5. FLAT BAR $\frac{5}{16}$" THK. WELDED TO TOP OF C12X25 TO MAKE ALUM. CHECKER TOP SLIGHTLY SLOPED AS INDICATED. LOCATE ℄ FLAT BAR TO MATCH ℄ CHANNEL BEFORE WELDING.

6. ANGLE 3"X2"X$\frac{5}{16}$" WELDED TO C12X25 8 $\angle$3"X2"X5/16" AT EACH END LENGTH SHALL EQUAL HALF OF LENGTH OR WIDTH OF VALVE MANHOLE.

Figure J8. Notes for raised cover plates.

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